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ROYAL AIRCRAFT ESTABLISHMENT

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Technical Report 81095

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TABLE OF SPACE VEHICLES, 1958 - 1980

by

H. Hiller
J. A. Pilkington

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Procurement Executive, Ministry of Defence
Farnborough, Hants

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SUMMARY

Details of all satellites launched into orbit about the Earth have been published in *The RAE Table of Earth Satellites, 1957-1980* (Macmillan Press, 1981). The present Report offers a similar listing, though in a different format, of all space vehicles that escaped from the Earth's influence as a result of the 109 space launchings during the years 1958-1980. Whenever possible, the following details are given for each component: name, international designation, date of launch, mass, basic shape and size, details of orbit or trajectory, and, where appropriate, the time and place of impact or landing on the Moon or a planet. The Table is in six sections: (A) orbits around the Sun; (B) in the Earth-Moon system; (C) and (D) around the Moon; (E) around Mars; and (F) around Venus.

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1 INTRODUCTION

In 1958 the RAE began issuing a record of satellites launched into orbit about the Earth: this Table of Earth Satellites has grown over the years, and the issues up to the end of 1980, suitably revised, have been published as a book of 672 pages¹. The Table of Satellites does not include spacecraft which escape from the Earth's influence, because they need a different format of tabulation.

So a separate Table of Space Vehicles was started in 1959, first issued² as an RAE Technical Report in 1966 and subsequently revised and expanded over the years. The last complete version was that issued in 1973³, and this is now superseded by the present Report, which records all launchings of space vehicles between January 1958 and the end of 1980.

The Table lists all the known components which escaped from the Earth's influence as a result of each space launching and, whenever possible, the following details are given for each component: name, international designation, date of launch, mass, basic shape and size, details of orbit or trajectory; in some sections of the Table there is also a 'remarks' column, where the time and place of impact or landing on the Moon or a planet, or the time and distance of flyby, are recorded.

The total number of launches to the end of 1980 was 109, of which 56 were by the USA, 51 by the USSR and two were FRG spacecraft launched by the USA. Most of the launches have given rise to at least two components, and with some launches, such as the Apollo Moon-landers, there are four or more components. In 57 of the 109 launches, a major instrumented payload was still in flight on 1 July 1981: the other 52 impacted or soft-landed on the Moon or a planet, or returned to Earth. However, there are believed to be some components (usually discarded rockets) still in flight from 100 of the 109 launches, often with unknown orbits. The rockets from the other nine launches either impacted on the Moon or decayed in the Earth's atmosphere.

The census table on page 4 provides a year-by-year enumeration of the launchings, classified according to their destination.

The main Table of Space Vehicles, which occupies pages 7-46 of this Report, is divided into six sections and, as components from some launches appear in more than one section, the Index (pages 47-49) should be used if details are needed of all components in a particular launch.

The first of the six sections includes any object that entered an orbit around the Sun, either en route to a planet or as a final orbit. Sections B-D record objects in the Earth-Moon system (Section B), and those in orbit around the Moon, Section C listing those launched from Earth and Section D those relaunched after soft-landing on the Moon. Sections E and F are for space vehicles that enter orbit around Mars and Venus respectively, after travelling from Earth in a heliocentric orbit. English names have been used in the titles of the sections, so that they will be more generally intelligible; the Greek terms (heliocentric, selenocentric, areocentric, etc) appear in the guide to the Table on pages 4-5.

Census of space vehicles 1958-1980

Year Destination	1958	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	Total 1958- 1980	Payload in orbit on 1 July 1981
Moon	2	4	0	0	3	1	2	7	9	8	6	6	4	4	3	2	2	0	1	0	0	0	0	64	19
Venus/Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0	0	0	0	0	0	1	1
Venus	-	-	-	1	1	0	1	2	0	2	0	2	1	0	1	0	0	2	0	0	4	0	0	17	10
Mars	-	-	-	-	1	0	2	0	0	0	0	2	0	3	0	4	0	2	0	0	0	0	0	15	15
Jupiter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0	0	0	0	0	0	0	1	1
Jupiter/ Saturn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0	0	2	0	0	0	0	3	3
Solar orbit	-	-	1	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	1	0	1	0	0	8	8
Total launches	2	4	1	1	5	1	6	10	10	11	7	10	5	7	5	8	3	4	2	2	5	0	0	109	
Payload in orbit on 1 July 1981	0	2	1	1	4	1	4	4	4	3	2	4	0	5	2	7	2	4	1	2	4	0	0		57

2 GUIDE TO THE TABLE OF SPACE VEHICLES

2.1 Letters in the left margin

The letters to the left of the first column have the following meanings:

- B denotes unmanned spacecraft which carried live biological specimens.
- D denotes space vehicles no longer in free flight on 1 July 1981.
- M denotes manned spacecraft; 2M indicates a crew of two at launch etc.
- R denotes spacecraft which returned to Earth and were recovered intact.
- T denotes spacecraft transmitting radio signals on 1 July 1981, either from orbit or from the surface of a planet after soft landing.

2.2 Section A: Orbits around the Sun (pages 7-20)

The first column of this listing of heliocentric orbits gives the name and international designation of the space vehicle. The second column gives the launch date in days and decimals of a day (UT). The next column gives the mass in kg (1 kg = 2.205 lb) and basic shape, *ie* ignoring solar panels and protuberances of all kinds. The fourth column gives the size of this basic shape in metres (1 m = 3.281 ft).

The next five columns give details of the orbit. The perihelion and aphelion distances are given in AU (1 Astronomical Unit = 149 500 000 km); these are followed by the eccentricity, orbital inclination to the ecliptic, and period of revolution about the Sun. Where two orbits are given, these refer to the trajectory before and after planetary flyby. The final column specifies the 'target' celestial body, and also gives the distance and date (UT) of nearest approach (flyby), or the impact time, or decay time in the 'target' atmosphere, or time of entry into orbit. (1 km = 0.6214 statute mile = 0.5396 nautical mile.)

For flyby, times are given in days and decimals of a day (UT); but for impacts and soft-landings, days, hours, minutes and seconds are given, since these times are measured more accurately. This time system also applies to Section B.

2.3 Section B: Orbits in the Earth-Moon system (pages 21-35)

As in Section A, the name, designation, launch date, mass, shape and size are given. In addition, since the flight of these vehicles is often terminated, the flight time is given; the maximum distance from the Earth (rather than the apogee distance of the initial orbit) is listed since the vehicle's path in a combined Earth-Moon field is often strongly influenced by the Moon; the Moon's age at launch is given, and also the all-burnt (the maximum) speed to show the comparison with escape (parabolic) speed, which is about 11.2 km/s at low heights near perigee; the final column gives the time and distance of flyby, or the time of impact or soft landing (UT) and selenocentric coordinates of the landing point (always called 'impact' for brevity). 'East' is measured to the right and 'North' upwards, from the centre of the Moon's visible disc, as seen from northerly latitudes on Earth.

2.4 Section C: Orbits around the Moon - Earth launch (pages 36-41)

The layout of the table for selenocentric orbits is based on the RAE Table of Earth Satellites¹ and applies to vehicles launched from Earth which go into orbit around the Moon. Three dates are given: the launch date; the injection date, which is the time of entry into selenocentric orbit; and the ejection or landing date, which is the time of departure from selenocentric orbit or the time of landing or impact on the Moon. (A landing or impact is indicated by the symbol \oplus .) Semi major axes are based on a Moon of radius 1738 km.

2.5 Section D: Orbits around the Moon - Moon launch (pages 42-3)

This section is reserved for spacecraft which, having successfully landed on the Moon are relaunched from the Moon's surface into selenocentric orbit (elliptic or hyperbolic). The layout is similar to that of Section C, except that the second column gives the Moon launch date and the date of descent either to the Moon's surface or to Earth.

2.6 Section E: Orbits around Mars - Earth launch (pages 44-5)

The layout is again similar to that of Section C, but applies to spacecraft launched from the Earth into a heliocentric orbit and later injected into orbit around Mars (areocentric orbit). This Section also includes the Mars landers which separated from the orbiting spacecraft. Semi major axes are based on a Mars radius of 3395 km.

2.7 Section F: Orbits around Venus - Earth launch (page 46)

The layout is again similar to that of Section C (except for column 2), but applies to spacecraft launched from Earth into heliocentric orbit which later enter orbit around Venus (cytherocentric orbit). Semi major axes are based on a Venus radius of 6052 km.

2.8 Multiple entries

Double entries may occur when a spacecraft orbiting the Moon (Section C) later lands on the Moon (Section B); or when an object in heliocentric orbit (Section A) goes into orbit around Mars or Venus (Section E or F). Sometimes components from one launch may appear in three sections, for example Apollo 11 (Sections A, B and C). The Index (pages 47-9) indicates the sections in which components from each launch are to be found.

3 SOURCES OF INFORMATION

We have made use of many sources of information, particularly NASA Press Releases for US spacecraft and translations of articles in *Pravda* for USSR spacecraft. Other sources include periodicals such as *Aviation Week*, *Flight International* and the *TRW Space Log*. Some trajectory parameters have been determined using Ref 4, particularly to check for errors or inconsistencies. Refs 5 and 6 are recommended as general surveys of Soviet lunar and planetary spacecraft; for the US spacecraft, numerous publications are available (eg Refs 7-10).

4 LUNAR AND PLANETARY 'FIRSTS'

As the progress of planetary exploration has been irregular, it may be useful to record the dates of the first flyby, impact, soft landing and orbiter for the Moon and each planet. They are given in the table below. (Please refer to the index (pages 47-9) for an indication of the pages where further details of each spacecraft may be found.)

<u>Planet</u>	<u>First flyby</u>	<u>First impact</u>	<u>First soft landing</u>	<u>First orbiter</u>
Moon	Luna 1 1959 Jan 4	Luna 2 1959 Sep 13	Luna 9 1966 Feb 3†	Luna 10 1966 Apr 3
Venus	Venus 1 1961 May 19	Venus 3 1966 Mar 1	Venus 7 capsule 1970 Dec 15	Venus 9 orbiter 1975 Oct 22
Mars	Mars 1 1963 Jun 19	Mars 2 lander 1971 Nov 27	Mars 3 lander 1971 Dec 2	Mariner 9 1971 Nov 14
Jupiter	Pioneer 10 1973 Dec 4	*	*	*
Mercury	Mariner 10 1974 Mar 29	-	-	-
Saturn	Pioneer 11 1979 Sep 1	-	-	-
Uranus	[Voyager 2 1986 Jan]	-	-	-
Neptune	[Voyager 2 1989 Aug?]	-	-	-

† First manned landing: Apollo 11 (LEM 5), 1969 July 20.

* First orbiter and descent into Jovian atmosphere expected to be the Galileo spacecraft due for launch in mid 1980s.

TABLE OF SPACE VEHICLES, 1958-1980

(A) Orbits around the Sun

Page 7

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Luna 1 (Merkat)	1959 Jan 2.71	362 sphere	0.9 dia	0.978	1.318	0.148	0.01	450	Passed 6000 km ahead of Moon on 1959 Jan 4.12
Luna 1 rocket	1959 Jan 2.71	1110 cylinder	2.6 dia 3.7 long		Orbit probably similar to 1959 v1				
Pioneer 4	1959 Mar 3.22	5.9 cone	0.56 dia 0.51 long	0.987	1.142	0.073	1.30	398	Passed 60000 km behind Moon on 1959 Mar 5.3
Pioneer 4 rocket	1959 Mar 3.22	5.9 cylinder	0.15 dia 1.08 long		Orbit probably similar to 1959 v1				Sergeant rocket
Pioneer 5	1960 Mar 11.54	41 sphere (+ 4 vanes)	0.66 dia	0.806	0.992	0.104	3.35	312	No specific target. Reached perihelion on 1960 Aug 14?
Pioneer 5 rocket	1960 Mar 11.54	23 cylinder	0.51 dia 1.22 long		Orbit probably similar to 1960 a1				
Venus 1	1961 Feb 12.09	643.5 cylinder	1.05 dia 2.03 long	0.713	1.019	0.173	0.58	300	Passed 100000 km from Venus during 1961 May 19-21
Venus 1 rocket	1961 Feb 12.09	cylinder 440	2.0 dia 2.0 long						No details available
Ranger 3	1962 Jan 26.85	330 hexagonal cylinder	1.52 dia 2.51 long	0.985	1.164	0.083	0.40	406	Passed 37000 km ahead of Moon on 1962 Jan 28.99
Ranger 3 rocket	1962 Jan 26.85	770? cylinder	1.52 dia 6.7 long						Apogee B. Orbit unknown

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Mariner 2	1962 ap1	203 hexagonal cylinder	1.52 dia 3.02 long	0.705	1.227	0.270	1.4	346	Passed 41000 km behind Venus on 1962 Dec 14.83
Mariner 2 rocket	1962 ap2	770? cylinder	1.52 dia 6.7 long						Agnes B. Orbit unknown
Ranger 5	1962 8n1	342 hexagonal cylinder	1.52 dia 2.51 long	0.951	1.064	0.056	0.41	369	Passed 735 km behind Moon on 1962 Oct 21.66
Ranger 5 rocket	1962 8n2	770? cylinder	1.52 dia 6.7 long						Agnes B. Orbit unknown
Mars 1	1962 8v1	893.5 cylinder	1.1 dia 3.3 long	0.924	1.604	0.269	2.68	519	Passed 193000 km from Mars on 1963 Jun 19
Mars 1 rocket	1962 8v4	cylinder 440	2.0 dia 2.0 long						Orbit unknown
Zond 1	1964-16D	850?	1 dia? 2.5 long?	0.652	1.001	0.211	3.7	274	Passed 100000 km from Venus on 1964 Jul 19
Zond 1 rocket	1964-16E	cylinder 440	2.0 dia 2.0 long						Orbit unknown
Mariner 3	1964-73A	261 octagonal cylinder	1.38 dia 0.46 long	0.983	1.311	0.143	0.52	448	Mars probe. Reached aphelion on 1965 Jun 17?
Mariner 3* rocket	1964-73B	1100 cylinder	1.52 dia 8 long?						Agnes D
				Orbit probably similar to 1964-73A					

* 1964-73B might not have separated from 1964-73A.

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Mariner 4	1964-77A	261 octagonal cylinder	1.38 dia 0.46 long	1.109	1.574	0.173	2.54	567	Passed 9850 km behind Mars on 1965 Jul 15.042
Mariner 4 rocket	1964-77B	1100 cylinder	1.52 dia 8 long?	0.990?	1.429?	0.181?	0.15?	486?	Agona D
Zond 2	1964-78C	900?	1 dia? 2.5 long?	0.98	1.52	0.22	6.40	508	Passed 1500 km from Mars on 1965 Aug 6
Zond 2 rocket	1964-78D	cylinder 440	2.0 dia 2.0 long						Orbit unknown
Zond 3	1965-56A	960 irregular	1 dia? 2.5 long?	0.90	1.56	0.25	0.5?	500	Passed 9220 km behind the Moon on 1965 Jul 20.10
Zond 3 rocket	1965-56D	cylinder 440	2.0 dia 2.0 long						Orbit unknown
Venus 2	1965-91A	963 cylinder	1.1 dia? 2.7 long?	0.716	1.197	0.252	4.29	341	Passed 24000 km from Venus on 1966 Feb 27.119
Venus 2 rocket	1965-91D	cylinder 440	2.0 dia 2.0 long						Orbit unknown
Venus 3	1965-92A	960 sphere- cylinder	sphere 0.91 dia	0.70?	1.11?	0.23?	4.29	316?	Hit Venus on 1966 Mar 1 at 6h 56m 26s. Impact <800 km from centre of visible disc
Venus 3 rocket	1965-92D	cylinder 440	2.0 dia 2.0 long						Orbit unknown

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Pioneer 6	1965-105A	64 cylinder	0.94 dia 0.89 long	0.814	0.985	0.095	0.17	311	Reached perihelion on 1966 May 19
Pioneer 6 rocket	1965-105C	24 cylinder	0.46 dia 1.5 long	Orbit probably similar to 1965-105A					Altair
Pioneer 7	1966-75A	64 octagonal cylinder	0.94 dia 0.89 long	1.012	1.125	0.054	0.10	403	Reached aphelion on 1967 Mar 8?
Pioneer 7 rocket	1966-75C	24 cylinder	0.46 dia 1.5 long	Orbit probably similar to 1966-75A					Altair
Venus 4 (capsule)	1967-58A	383 sphere	1.2 dia	0.70?	1.11?	0.23?	4.3?	316?	Crushed by Venus atmosphere near equator on 1967 Oct 18 at 6h 14m 6s
Venus 4 (compartment)	1967-58F	723 ellipsoid	1.2 dia 1.7 long?	0.70?	1.11?	0.23?	4.3?	316?	Decayed in Venusian atmosphere 1967 Oct 18 at 4h 40m
Venus 4 rocket	1967-58E	cylinder 440	2.0 dia 2.0 long	Orbit unknown					Orbit unknown
Mariner 5	1967-60A	246 octagonal cylinder	1.27 dia 2.90 long	0.579	0.735	0.119	1.37	195*	Passed 4000 km behind Venus on 1967 Oct 19.733
Mariner 5 rocket	1967-60B	1100? cylinder	1.52 dia 7 long	Agena D. Missed Venus					
Explorer 35 third stage rocket	1967-70C	24 cylinder	0.46 dia 1.5 long	0.99?	1.02?	0.012?	0.5?	367?	Altair. Passed Moon on 1967 Jul 22.6

* Orbit after Venus flyby.

(A) Orbits around the Sun (continued)

Page 11

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Pioneer 8	1967 Dec 13.589	66 cylinder	0.94 dia 0.89 high	0.990	1.087	0.047	0.06	386	Reached aphelion on 1968 Jun 23?
Pioneer 8 rocket	1967 Dec 13.589	24 cylinder	0.46 dia 1.5 long	Orbit probably similar to 1967-123A					Altair
Pioneer 9	1968 Nov 8.407	66 cylinder	0.94 dia 0.89 high	0.756	0.990	0.134	0.09	298	Reached perihelion about 1969 Apr 5
Pioneer 9 rocket	1968 Nov 8.407	24 cylinder	0.46 dia 1.5 long	Orbit probably similar to 1968-100A					Altair
Apollo 8 rocket	1968 Dec 21.54	13000? cylinder	6.6 dia 24.5 long?	0.923	0.988	0.034	0.5?	341	Saturn IVB. Passed 1445 km behind Moon on 1968 Dec 24.4
Venus 5 (capsule)	1969 Jan 5.269	405 sphere	1.0 dia	0.72?	1.08?	0.20?	2?	313?	Crushed by Venus atmosphere on 1969 May 16 at 6h 53m
Venus 5 (compartment)	1969 Jan 5.269	725 cylinder + 2 vanes	1.22 dia 2.5 long	0.72?	1.08?	0.20?	2?	313?	Decayed in Venus atmosphere on 1969 May 16 at 6h 1m
Venus 5 rocket	1969 Jan 5.269	440 cylinder	2.0 dia 2.0 long	Passed 25000 km from Venus?					
Venus 6 (capsule)	1969 Jan 10.244	405 sphere	1.0 dia	0.72?	1.08?	0.20?	2?	313?	Crushed by Venus atmosphere on 1969 May 17 at 6h 58m
Venus 6 (compartment)	1969 Jan 10.244	725 cylinder + 2 vanes	1.22 dia 2.5 long	0.72?	1.08?	0.20?	2?	313?	Decayed in Venus atmosphere on 1969 May 17 at 6h 2m
Venus 6 rocket	1969 Jan 10.244	440 cylinder	2.0 dia 2.0 long	Passed 150000 km from Venus?					

D

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(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Mariner 6	1969 Feb 25.062	413 octagonal frame	1.38 dia 0.46 long	0.990 1.142	1.588 1.754	0.232 0.211	1.94 1.78	535 636	Passed 3430 km behind Mars on 1969 Jul 31.222
Mariner 6 rocket	1969 Feb 25.062	1815 cylinder	3.05 dia 8.14 long	0.970	1.593	0.243	2.06	529	Centaur
Apollo 9 rocket	1969 Mar 3.67	13430 cylinder	6.6 dia 18.7 long	0.546	0.991	0.290	0.5?	248	Saturn IVB. Missed Moon
Mariner 7	1969 Mar 27.932	413 octagonal frame	1.38 dia 0.46 long	0.971 1.118	1.568 1.670	0.235 0.198	1.60 1.82	522 609	Passed 3430 km behind Mars on 1969 Aug 5.209
Mariner 7 rocket	1969 Mar 27.932	1815 cylinder	3.05 dia 8.14 long	0.991	1.637	0.246	1.69	549	Centaur
Apollo 10 rocket	1969 May 18.70	13600 cylinder	6.6 dia 18.7 long	0.908	1.017	0.057	0.5?	345	Saturn IVB. Passed 3500 km? behind Moon on 1969 May 21.9
LEM 4* ascent stage	1969 May 18.70	2169 box + 2 tanks	2.52 high 3.76 wide 3.13 deep						Launched from scieno- centric orbit 1969 May 23.26
Apollo 11 rocket	1969 Jul 16.564	13300 cylinder	6.6 dia 18.7 long	0.891	1.016	0.066	0.5?	342	Saturn IVB. Passed 3500 km? behind Moon on 1969 Jul 19.7

* See also pages 28 and 37.

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
D Venus 7 [†] (capsule)	1970 Aug 17.23	455 sphere	1.0 dia	0.72?	1.08?	0.20?	2?	313?	Soft-landed on Venus 1970 Dec 15 at 05h 34m 10s at 50°S, 351°E long
D Venus 7 (compartment)	1970 Aug 17.23	725 cylinder + 2 vanes	1.22 dia 2.5 long	0.72?	1.08?	0.20?	2?	313?	Decayed in Venus atmosphere on 1970 Dec 15 at 05h 02m
Venus 7 rocket	1970 Aug 17.23	440 cylinder	2.0 dia 2.0 long						Orbit unknown
Mars 2*	1971 May 19.683	4650 (incl. fuel) cylinder-cone	2.5 dia 3.8 long	0.99?	1.57?	0.23?	2.2?	530?	Entered Mars orbit on 1971 Nov 27.85. Capsule hit Mars 1971 Nov 27.85
Mars 2 rocket	1971 May 19.683	cylinder 1900?	3.9 dia 3.9 long?		Orbit probably similar to 1971-45A				Proton escape stage
Mars 3*	1971 May 28.640	4650 (incl. fuel) cylinder + cone	2.5 dia 3.8 long	0.99?	1.57?	0.23?	2.2?	530?	Entered Mars orbit 1971 Dec 2.57. Capsule soft- landed 1971 Dec 2 at 13h 49m 5s. Impact: 45°S, 158°W
Mars 3 rocket	1971 May 28.640	cylinder 1900?	3.9 dia 3.9 long?		Orbit probably similar to 1971-49A				Proton escape stage
Mariner 9*	1971 May 30.933	975 (incl. fuel) octagon + 2 tanks	1.38 dia 2.29 long	0.99?	1.57?	0.23?	2.2?	530?	Entered Mars orbit on 1971 Nov 14.02
Mariner 9 rocket	1971 May 30.933	1815 cylinder	3.05 dia 8.14 long		Orbit probably similar to 1971-51A				Centaur

* See also page 44.

† Parachute descent took 32 min; surface transmission lasted 23 min.

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
T Pioneer 10	1972-12A	250 hexagon + dish	2.75 dia 1.45 long	0.991 0.98?	5.864 =	0.711 1.21	1.31? 1.31?	2318 -	Passed 130400 km behind Jupiter on 1973 Dec 4.10
Pioneer 10 rocket	1972-12B	66 sphere + nozzle	0.94 dia 1.32 long	Orbit probably similar to 1972-12A					Up-rated Surveyor Retrorocket
D Venus 8 [†] (capsule)	1972-21A	495 sphere	1.0 dia	0.72?	1.08?	0.20?	2?	313?	Soft-landed on Venus day side 1972 Jul 22 at 09h 29m
D Venus 8 (compartment)	1972-21E	689 cylinder + 2 vanes	1.22 dia 2.5 long	0.72?	1.08?	0.20?	2?	313?	De-ayed in Venus atmosphere, 1972 Jul 22 at 08h 38m
Venus 8 rocket	1972-21D	440 cylinder	2.0 dia 2.0 long	Orbit unknown					
T Pioneer 11	1973-19A	259 hexagon + dish	2.75 dia 1.45 long	1.000 0.98?	6.012 =	0.715 1.21	1.31? 1.31?	2398 -	Passed 41850 km below Jupiter on 1974 Dec 3.224
Pioneer 11 rocket	1973-19B	66 sphere + nozzle	0.94 dia 1.32 long	Orbit probably similar to 1973-19A					Up-rated Surveyor Retrorocket

* Expected final path apex near R.A. 04h 33.0m; Declination 16.42°N. Occulted by Jovian satellite Io on 1973 Dec 4.11.

** Pioneer 11 passed 20200 km from Saturn's cloud tops (just outside rings) on 1979 Sep 1.69; closest approaches to Saturn's moons are as follows:
Phoebe (950000 km on Aug 27), Iapetus (1000000 km on Aug 28), Hyperion (674000 km on Aug 31), Dione (291000 km on Sep 1.67), Mimas (103000 km on Sep 1.68), then Tethys (332000 km on Sep 1.77), Enceladus (225000 km on Sep 1.78), Rhea (342000 km on Sep 1.94) and finally Titan (355000 km on Sep 2). Will leave solar system in 1993.

[†] Parachute descent took 51 min; surface transmitters lasted 50 min. Location: at 10°S, 335° long.

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Mars 4* orbiter	1973 Jul 21.813	3440? full cylinder + 2 panels	2.3 dia 2.7 long	1.02?	1.63?	0.23?	2.2?	556?	Passed 2200 km behind Mars on 1974 Feb 10
Mars 4 rocket	1973 Jul 21.813	1900? cylinder	3.9 dia 3.9 long?	Orbit probably similar to 1973-47A					Proton escape stage
Mars 5 orbiter	1973 Jul 25.789	3440? full cylinder + 2 panels	2.3 dia 2.7 long	1.01?	1.65?	0.24?	2.2?	560?	Entered areocentric orbit on 1974 Feb 12.66. See page 44
Mars 5 rocket	1973 Jul 25.789	1900? cylinder	3.9 dia 3.9 long?	Orbit probably similar to 1973-49A					Proton escape stage
Mars 6 compartment	1973 Aug 5.740	2060? empty cylinder + 2 panels	2.3 dia 2.7 long	1.01?	1.67?	0.24?	2.2?	567?	Passed 1600 km behind Mars on 1974 Mar 12.38
Mars 6 capsule**	1973 Aug 5.740	1200? full 635 empty cone-sphere	2.5 dia 1.1 long	1.01?	1.67?	0.24?	2.2?	567?	Soft-landed on Ma.s 1974 Mar 12 at 24°S, 25°W
Mars 6 rocket	1973 Aug 5.740	1900? cylinder	3.9 dia 3.9 long?	Ejected onto impact path 1974 Mar 12					Proton escape stage
Mars 7 compartment	1973 Aug 9.708	2060? empty cylinder + 2 panels	2.3 dia 2.7 long	1.01?	1.69?	0.25?	2.2?	574?	Passed 1300 km behind Mars on 1974 Mar 9
Mars 7 [†] capsule	1973 Aug 9.708	1200? full 635 empty cone-sphere	2.5 dia 1.1 long	1.01?	1.69?	0.25?	2.2?	574?	Passed 1300 km behind Mars on 1974 Mar 9

* Areocentric orbit insertion engine failed.

** Transmissions ceased on landing, at 09h 11m 05s UT.

† Capsule separated from compartment correctly 48000 km from Mars, but its small motor failed to put it on a collision course.

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Mars 7 rocket	1973-53E 1973 Aug 9.708	1900? cylinder	3.9 dia 3.9 long?		Orbit probably similar to 1973-53A				Proton escape stage
Mariner 10*	1973-85A 1973 Nov 3.24	526 octagonal cylinder	1.27 dia 2.90 long?	0.70 0.387	1.11 0.839	0.23 0.369	2.6 2.6	317 176	Passed 5750 km ahead of Venus 1974 Feb 5.71
Mariner 10 rocket	1973-85B 1973 Nov 3.24	1815 cylinder	3.05 dia 8.14 long		Orbit probably similar to 1973-85A				Centaur. Passed 45000 km behind Venus
Helios 1	1974-97A 1974 Dec 10.299	370 double-cone	1.75 to 2.77 dia 2.18 long	0.307	0.985	0.525	0	190	At perihelion on 1975 Mar 15.47
Helios 1 rocket	1974-97C 1974 Dec 10.299	66 sphere + nozzle	0.94 dia 1.32 long		Orbit probably similar to 1974-97A				Up-rated Surveyor Retro-rocket
Fragment	1974-97E								
Venus 9 orbiter	1975-50A 1975 Jun 8.109	3376 full cylinder + 2 panels	2.3 dia 2.7 long 5.7 span	0.70?	1.11?	0.23?	2.3?	316?	Entered orbit round Venus on 1975 Oct 22.17. See page 46
Venus 9 lander**	1975-50D 1975 Jun 8.109	1560 sphere- annulus	2.4 dia sphere	0.70?	1.11?	0.23?	2.3?	316?	Soft-landed on Venus day side on 1975 Oct 22 at 05h 13m 07s
Venus 9 rocket	1975-50E 1975 Jun 8.109	1900? cylinder	3.9 dia 3.9 long?		Orbit probably similar to 1975-50A				Proton escape stage

* Passed 700 km ahead of Mercury (night side) on 1974 Mar 29.87;
passed 48000 km below Mercury's South Pole on 1974 Sep 21.874;
passed 330 km from Mercury on 1975 Mar 16.94. Transmissions ceased on 1975 Mar 24.

** Parachute descent took 75 min; surface transmissions lasted 53 min. Location - at 31° 41'N, 293° 50' long. (Inside region Beta).

Helios is German spacecraft
launched by US rocket.

(A) Orbits around the Sun (continued)

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Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Venus 10 orbiter	1974 Jun 14.13	3473 full cylinder + 2 panels	2.3 dia 2.7 long 5.7 span	0.70?	1.11?	0.23?	2.3?	316?	Entered orbit round Venus on 1975 Oct 25.17. See page 46
Venus 10 lander*	1975 Jun 14.13	1560 sphere- annulus	2.4 dia sphere	0.70?	1.11? Ejected onto impact path 1975 Oct 23	0.23?	2.3?	316?	Soft-landed on Venus day side on 1975 Oct 25 at 05h 17m 06s
Venus 10 rocket	1975 Jun 14.13	1900? cylinder	3.9 dia 3.9 long?		Orbit probably similar to 1975-54A				Proton escape stage
Viking 1 orbiter	1975 Aug 20.890	2325 full octagonal box + 4 vanes	3.3 high 1.8 wide 1.5 deep	1.003	1.672	0.250	4.48	565	Entered areocentric orbit on 1976 Jun 19, then ejected lander
Viking 1 lander	1975 Aug 20.890	1090 full 600 empty pyramid	2.1 high** 3.0 wide 2.5 deep	1.003	1.672	0.250	4.48	565	Soft-landed on Mars 1976 Jul 20 at 12h 12m. Site 22.27°N, 47.94°W
Viking 1 rocket	1975 Aug 20.890	1815 cylinder	3.05 dia 8.14 long		Orbit similar to 1975-75A				Centaur. Passed 80500 km from Mars
Viking 2 orbiter	1975 Sep 9.777	2325 full octagonal box + 4 vanes	3.3 high 1.8 wide 1.5 deep	1.006	1.669	0.248	2.92	565	Entered areocentric orbit on 1976 Aug 7.47, then ejected lander
Viking 2 lander	1975 Sep 9.777	1090 full 600 empty pyramid	2.1 high** 3.0 wide 2.5 deep	1.006	1.669	0.248	2.92	565	Soft-landed on Mars 1976 Sep 3 at 22h 58m. Site 47.67°N, 225.71°W
Viking 2 rocket	1975 Sep 9.777	1815 cylinder	3.05 dia 8.14 long		Orbit similar to 1975-83A				Centaur. Passed 80500 km from Mars

* Parachute descent took 75 min; surface transmissions lasted 65 min. Landed 2200 km from Venus 9, at 16° 02'N, 291° 00' long.

** Including legs.

Viking areocentric orbits - see pages 44 and 45.

(A) Orbits around the Sun (continued)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
T Helios 2 1976-03A	1976 Jan 15.23	376 double-cone	1.75 to 2.77 dia 2.18 long	0.28	0.995	0.561	0	86	At perihelion on 1976 Apr 17
Helios 2 second stage 1976-03B	1976 Jan 15.23	1815 cylinder	3.05 dia 8.14 long			Orbit unknown			Centaur
Helios 2 rocket 1976-03C	1976 Jan 15.23	66 sphere + nozzle	0.94 dia 1.32 long			Orbit probably similar to 1976-03A			Up-rated Surveyor Metrorocket
Voyager 2 1977-76A	1977 Aug 20.603	795 decagon + dish	1.9 and 3.7 dia 1.5 long			To exceed solar escape velocity			Flyby of four outer planets*
Voyager 2 second stage 1977-76B	1977 Aug 20.603	1815 cylinder	3.05 dia 8.14 long			Unknown heliocentric orbit			Centaur
Voyager 2 rocket 1977-76C	1977 Aug 20.603	66 sphere + nozzle	0.94 dia 1.32 long			Orbit probably similar to 1977-76A			Up-rated Surveyor Metrorocket
Voyager 1 1977-84A	1977 Sep 5.539	795 decagon + dish	1.9 and 3.7 dia 1.5 long			To exceed solar escape velocity			Jupiter and Saturn flyby**
Voyager 1 second stage 1977-84B	1977 Sep 5.539	1815 cylinder	3.05 dia 8.14 long			Unknown heliocentric orbit			Centaur
Voyager 1 rocket 1977-84C	1977 Sep 5.539	66 sphere + nozzle	0.94 dia 1.32 long			Orbit probably similar to 1977-84A			Up-rated Surveyor Metrorocket

* Passed 642000 km from Jupiter on 1979 Jul 10 (206000 km from Europa). Passed 101000 km from Saturn on 1981 Aug 26.14 (87000 km from Enceladus, 93000 km from Tethys, 666900 km from Titan). Should reach Uranus in 1986 January, followed by a planned flyby of Neptune about 1989 August.

** Passed 280000 km from Jupiter on 1979 Mar 5.5 (19000 km from Io, 112000 km from Ganymede, 732000 km from Europa; and on Mar 6 124000 km from Callisto); then passed 124000 km under Saturn on 1980 Nov 13.04 (4000 km from Titan on 1980 Nov 12.29). Will leave solar system about 1990 in direction constellation Ophiuchus.

(A) Orbits around the Sun (continued)

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Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
Pioneer Venus orbiter	1978 May 20.55	580 full 370 empty cylinder	2.4 dia 1.2 long	0.70?	1.30?	0.30?	2.3?	365?	Entered Venus orbit on 1978 Dec 4.665. See page 46
Orbiter rocket	1978 May 20.55	1815 cylinder	3.0 dia 8.6 long		Orbit similar to 1978-51A				Centaur
Pioneer Venus Multiprobe Bus	1978 Aug 8.31	309* cylinder	2.4 dia 1.2 long*	0.70?	1.11?	0.23?	2.3?	316?	Decayed in Venus atmosphere on 1978 Dec 9 at 20h 25m near 33°S, 70°W
Large probe** (Sounder)	1978 Aug 3.31	316 sphere + cone	1.5 dia		Ejected from Bus 1978 Nov 16.11				Venus landing 1978 Dec 9 at 19h 43m, near 0°S, 43°W
Small probe 1 (North)	1978 Aug 8.31	93 sphere + cone	0.8 dia		Ejected from Bus 1978 Nov 20.55				Venus landing 1978 Dec 9 at 19h 46m, near 75°W, 20°E
Small probe 2 (Day)	1978 Aug 8.31	93 sphere + cone	0.2 dia		Ejected from Bus 1978 Nov 20.55				Venus landing 1978 Dec 9 at 19h 51x, near 26°S, 45°W
Small probe 3 (Night)	1978 Aug 8.31	93 sphere + cone	0.8 dia		Ejected from Bus 1978 Nov 20.55				Venus landing 1978 Dec 9 at 19h 55m, near 27°S, 45°E
Pioneer Venus rocket	1978 Aug 8.31	1815 cylinder	3.0 dia 8.6 long		Orbit similar to 1978-78A				Centaur

* Excluding probes (total mass 904 kg).

** Transmitted for about 68 min after Venus landing. Four probes' atmospheric descent took about 57 min; coordinates are with respect to Venus's disc seen from Earth at time of encounter.

(A) Orbits around the Sun (concluded)

Name	Launch date (UT)	Mass (kg) and basic shape	Basic size (m)	Perihelion (AU)	Aphelion (AU)	Eccentricity	Inclination to ecliptic (deg)	Period (days)	Remarks
ISPE 3 [†]	1978 Aug 12.63	469 full 16-sided polyhedron	1.73 dia 1.61 long	0.973	1.006	0.017	0.0	359	International Sun- Earth Explorer
Venus 11 transit module	1978 Sep 9.15	2380? empty cylinder + 2 panels	3.3 dia 2.7 long 5.7 span	0.70?	1.11?	0.23?	2.3?	316?	Passed 35000 km from Venus on 1978 Dec 25
Venus 11 lander*	1978 Sep 9.15	1560? sphere- annulus	2.4 dia sphere	0.70?	1.11?	0.23?	2.3?	316?	Soft-landed on Venus on 1978 Dec 25 at 03h 24m
Venus 11 rocket	1978 Sep 9.15	1900? cylinder	3.9 dia 3.9 long?	Orbit similar to 1978-84A					Proton escape stage
Venus 12 transit module	1978 Sep 14.11	2380? empty cylinder + 2 panels	2.3 dia 2.7 long 5.7 span	0.70?	1.11?	0.23?	2.3?	316?	Passed 35000 km from Venus on 1978 Dec 21
Venus 12 lander**	1978 Sep 14.11	1560? sphere- annulus	2.4 dia sphere	0.70?	1.11?	0.23?	2.3?	316?	Soft-landed on Venus on 1978 Dec 21 at 03h 30m
Venus 12 rocket	1978 Sep 14.11	1900? cylinder	3.9 dia 3.9 long?	Orbit similar to 1978-86A					Proton escape stage

[†] Entered heliocentric orbit - a 'halo' orbit around the Sun-Earth/Moon libration point, at a distance of 1.6 million km from Earth on Earth-fun line.
(Location maintained by micro-thrusters.)

* Surface transmissions lasted 95 min. Location: 14°S, 299° long.

** Surface transmissions lasted 110 min. Location: 7°S, 294° long. (Two landers are 800 km apart.)

(B) Orbits in the Earth-Moon system

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Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D Pioneer 1	1958 n 1958 Oct 11.36 43.3 hours	38 cone	0.74 dia 0.76 long	120000	27.9	10.52	Decayed 1958 Oct 13 at 03h 56m in Earth's atmosphere
D Pioneer 3	1958 o 1958 Dec 6.24 38.1 hours	5.9 cone	0.25 dia 0.58 long	110000	25.0	10.5	Decayed 1958 Dec 7 at 19h 52m in Earth's atmosphere
D Luna 2	1959 £1 1959 Sep 12.46? 34 hours	390 sphere	0.9 dia	400000	9.4	11.2	Hit Moon 1959 Sep 13 at 21h 02m 23s. Impact: 1°W; 30°N
D Luna 2 rocket	1959 £2 1959 Sep 12.46? 34 hours	1121 cylinder	2.6 dia 3.7 long	400000	9.4	11.2	Hit Moon near Luna 2
D Luna 3	1959 o1 1959 Oct 4.1 6 months	278 ellipsoid	1.20 dia 1.30 long	483000	1.6	11.0	Passed 6200 km behind Moon on 1959 Oct 10.91. Decayed in Earth's atmosphere 1960 Mar 29?
D? Luna 3 rocket	1959 o2 1959 Oct 4.1 6 months?	1275 cylinder	2.6 dia 3.7 long	-	1.6	11.0	Orbit unknown
D? Small booster	1959 o3 1959 Oct 4.1 6 months?	cylinder 157?	-	-	1.6	-	Separated from Luna 3. Orbit unknown
D Ranger 4	1962 u1 1962 Apr 23.868 64.01 hours	331 cylinder (hexagonal)	1.52 dia 2.51 long	400000	19.0	11.0	Hit Moon 1962 Apr 26 at 12h 49m 53s. Impact: 130.7°W; 15.5°S
Ranger 4 rocket	1962 u2 1962 Apr 23.868	770? cylinder	1.52 dia 6.7 long?	-	19.0	11.0?	Agona B. Missed Moon. Could be in helio-centric orbit
Luna 4	1963-08A* 1963 Apr 2.3	1422 cylinder	1 dia? 2.5 long?	690000	7.9	10.94	Passed 8500 km from Moon on 1963 Apr 6.06
Luna 4 rocket	1963-08B† 1963 Apr 2.3	cylinder 440	2.0 dia 2.0 long	-	7.9	10.94	Orbit unknown

* Designated 1963-08B in the USA.

† Not catalogued in the USA.

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D Ranger 6	1964-07A 1964 Jan 30.659 65.592 hours	365 cylinder (hexagonal)	1.52 dia 2.51 long	400000	15.8	10.97	Hit Moon 1964 Feb 2 at 09h 24m 33s. Impact: 9.2°N; 21.5°E
Ranger 6 rocket	1964-07B 1964 Jan 30.659	770? cylinder	1.52 dia 6.7 long?	-	15.8	10.97	Agna B. Passed 3700 km behind the Moon. Could be in heliocentric orbit
D Ranger 7	1964-41A 1964 Jul 28.701 68.595 hours	366 cylinder (hexagonal)	1.52 dia 2.51 long	400000	19.2	10.98	Hit Moon 1964 Jul 31 at 13h 25m 49s. Impact: 10.7°S; 20.7°W
Ranger 7 rocket	1964-41B 1964 Jul 28.701	770? cylinder	1.52 dia 6.7 long?	-	19.2	10.98?	Agna B. Missed the Moon. In high- eccentricity orbit
D Ranger 8	1965-10A 1965 Feb 17.712 64.87 hours	367 cylinder (hexagonal)	1.52 dia 2.51 long	400000	16.0	11.0	Hit Moon 1965 Feb 20 at 09h 57m 38s. Impact: 2.7°N; 24.8°E
Ranger 8 rocket	1965-10B 1965 Feb 17.712	770? cylinder	1.52 dia 6.7 long?	650000?	16.0	11.0	Agna B. Missed the Moon by 16000 km on 1965 Feb 20.7. In high-eccentricity orbit
D Ranger 9	1965-23A 1965 Mar 21.901 64.522 hours	366 cylinder (hexagonal)	1.52 dia 2.51 long	400000	18.5	11.0	Hit Moon 1965 Mar 24 at 14h 08m 20s. Impact: 12.9°S; 2.4°W
Ranger 9 rocket	1965-23B 1965 Mar 21.901	770? cylinder	1.52 dia 6.7 long?	-	18.5	11.0	Agna B. Missed the Moon. Could be in heliocentric orbit
D Luna 5	1965-36A 1965 May 9.33 83.22 hours	1476 sphere- cylinder	1.0 dia? 2.5 long?	400000	7.8	10.95	Hit Moon 1965 May 12 at 19h 10m. Impact: 31°S; 8°W
Luna 5 rocket	1965-36D 1965 May 9.33	cylinder 440	2.0 dia 2.0 long	-	7.8	10.95	Orbit unknown

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
Luna 6	1965-44A	1442 sphere-cylinder	1.0 dia? 2.5 long?	-	8.4	10.95	Missed Moon by 160000 km on 1965 Jun 11.7. Could be in heliocentric orbit
Luna 6 rocket	1965-44D	cylinder 440	2.0 dia 2.0 long	-	8.4	10.95	Orbit unknown
Luna 7	1965-77A	1506 sphere-cylinder	1.0 dia? 2.5 long?	400000	9.2	10.94	Hit Moon 1965 Oct 7 at 22h 08m 24s. Impact: 90°N; 40°W
Luna 7 rocket	1965-77D	cylinder 440	2.0 dia 2.0 long	-	9.2	10.94	Orbit unknown
Luna 8	1965-99A	1552 sphere-cylinder	1.0 dia? 2.5 long?	400000	10.3	10.95	Hit Moon 1965 Dec 6 at 21h 51m 30s. Impact: 9.1°N; 63.3°W
Luna 8 rocket	1965-99D	cylinder 440	2.0 dia 2.0 long	-	10.3	10.95	Orbit unknown
Luna 9	1966-06A	100 sphere	0.7 dia	400000	9.8	10.96?	Soft-landed on Moon 1966 Feb 3 at 18h 45m 30s. Impact: 7.1°N; 64.4°W
Luna 9 retrorocket	1966-06E	1483 (incl. fuel) cylinder	1.0 dia 1.8 long	400000	9.8	10.96?	Hard-landed on Moon 1966 Feb 3 at 18h 45m 30s. Impact: 7.1°N; 64.4°W
Fragments*	1966-06F,G						Hit Moon near Luna 9
Luna 9 rocket	1966-06D	cylinder 440	2.0 dia 2.0 long	-	9.8	-	Missed Moon. In high-eccentricity orbit.
Luna 10 rocket	1966-27D	cylinder 440	2.0 dia 2.0 long	-	9.3	10.87	Missed Moon. Could be in heliocentric orbit
Fragments*	1966-27E,F						In high-eccentricity orbit

* A control unit (two separate pieces) separated from the retrorocket before it fired.

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
Surveyor 1 1966-45A	1966 May 30.612 63.61 hours	281 pyramid frame	3.05 high 4.27 dia (of tripod)	400000	10.2	10.51	Soft-landed on Moon 1966 Jun 2 at 6h 17m 34s. Impact: 43.21°N; 2.45°S
Surveyor 1 1966-45B rocket	1966 May 30.612	2000 cylinder	3.05 dia 9.1 long	660000	10.2	10.51	Centaur. Passed 17000 km behind Moon 1966 Jun 2.526
Surveyor 1 1966-45C retrorocket	1966 May 30.612 63.6 hours	66 sphere (+ nozzle)	0.94 dia 1.32 long	400000	10.2	10.51	Hit Moon 1966 Jun 2 near Surveyor 1
Lunar Orbiter 1 1966-73A	1966 Aug 10.810 80.00 days	386 truncated cone	1.52 dia 1.68 high	400000	23.6	10.91	Sent crashing into Moon from selenocentric orbit on 1966 Oct 29 at 19h 26m. Impact: 6.7°N; 162°E
Lunar Orbiter 1 1966-73B rocket	1966 Aug 10.810	1000? cylinder	1.52 dia 7 long	-	23.6	10.91	Agenda D. Passed 8400 km behind Moon. In high-eccentricity orbit
Luna 11 1966-78D rocket	1966 Aug 24.34	cylinder 440	2.0 dia 2.0 long	-	7.8	-	Orbit unknown
Surveyor 2* 1966-84A	1966 Sep 20.522 62.8 hours	292 pyramid frame	3.05 high 4.27 dia (of tripod)	400000	5.7	10.52	Hit Moon 1966 Sep 23 at 03h 20m. Impact: near 25°N; 5°E
Surveyor 2 1966-84B rocket	1966 Sep 20.522	2000 cylinder	3.05 dia 9.1 long	-	5.7	10.52	Centaur. Missed Moon. In high-eccentricity orbit
Luna 12 1966-94D rocket	1966 Oct 22.37	cylinder 440	2.0 dia 2.0 long	-	8.2	-	Orbit unknown
Lunar Orbiter 2 1966-100A	1966 Nov 6.973 338.33 days	389 truncated cone	1.52 dia 1.68 high	400000	23.8	10.90?	Sent crashing into Moon from selenocentric orbit on 1967 Oct 11 at 7h 11m. Impact: 4°S; 98°E
Lunar Orbiter 2 1966-100B rocket	1966 Nov 6.973 8.90 days	1000? cylinder	1.52 dia 7 long	350000	23.8	10.90?	Agenda D. Decayed 1966 Nov 15 at 21h 0m in Earth's atmosphere

* 0.91 m diameter spherical retrorocket (mass 64 kg) may not have separated.

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D Luna 13	1966-116A 1966 Dec 21.428 79.75 hours	100? sphere	0.7 dia?	400000	9.3	10.96?	Soft-landed on Moon 1966 Dec 24 at 18h 01m 26s. Impact: 18.87°N; 62.01°W
Luna 13 rocket	1966-116D 1966 Dec 21.428	cylinder 440	2.0 dia 2.0 long	-	9.3	10.96?	Missed Moon
D Luna 13 retrorocket	1966-116E 1966 Dec 21.428 79.75 hours	1600? (incl. fuel) cylinder	1.0 dia? 1.8 long?	400000	9.3	10.96?	Hard-landed on Moon 1966 Dec 24 at 18h 01m 26s. Impact: 18.87°N; 62.01°W
D Lunar Orbiter 3	1967-08A 1967 Feb 5.053 246.38 days	389 truncated cone	1.52 dia 1.68 high	400000	25.2	10.90?	Sent crashing into Moon from selenocentric orbit on 1967 Oct 9 at 10h 27m 11s. Impact: 91.7°W; 14.6°N
Lunar Orbiter 3 rocket	1967-08B 1967 Feb 5.053	1000? cylinder	1.52 dia 7 long	-	25.2	10.90?	Agona D. Missed Moon
D Surveyor 3*	1967-35A 1967 Apr 17.295 64.99 hours	302 pyramid frame	3.05 high 4.27 dia (of tripod)	400000	7.4	10.6	Soft-landed on Moon 1967 Apr 20 at 0h 4m 17s. Impact: 3.20°S; 23.38°W
Surveyor 3 rocket	1967-35B 1967 Apr 17.295	2000 cylinder	3.05 dia 9.1 long	-	7.4	10.6	Centaur. In high-eccentricity orbit of period about 10 days
D Lunar Orbiter 4	1967-41A 1967 May 4.934 154 days	390 truncated cone	1.52 dia 1.68 high	400000	25.0	10.85	Decayed naturally from selenocentric orbit and hit Moon 1967 Oct 6 at 12h?
Lunar Orbiter 4 rocket	1967-41B 1967 May 4.934	1000? cylinder	1.52 dia 7 long	-	25.0	10.85	Agona D. Missed Moon

* Surveyor 3 retrorocket (0.94 m diameter sphere of mass 66 kg) separated and landed close by.

(B) Orbits in the Earth-Moon system (continued)

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Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
Surveyor 4*	1967-68A 1967 Jul 14.495 62.21 hours	302 pyramid frame	3.05 high 4.27 dia (of tripod)	400000	6.8	10.6	Landed on Moon 1967 Jul 17 at 2h 5m. Impact: 0.4°N; 1.33°W
Surveyor 4 rocket	1967-68B 1967 Jul 14.495	2000 cylinder	3.05 dia 9.1 long	414000	6.8	10.6	Centaur. In high-eccentricity orbit (period about 11 days). Passed 23000 km from Moon 1967 Jul 17.42
Lunar Orbiter 5	1967-75A 1967 Aug 1.940 182.39 days	390 truncated cone	1.52 dia 1.68 high	400000	25.3	10.91	Sent crashing into Moon from selenocentric orbit 1968 Jan 31 at 07h 58m 10s. Impact: 2.8°S; 83.0°W
Lunar Orbiter 5 rocket	1967-75B 1967 Aug 1.940	1000 cylinder	1.52 dia 7 long	370000	25.3	10.91	Agna D. In high-eccentricity orbit (period about 10 days). Passed 25000 km from Moon
Surveyor 5	1967-84A 1967 Sep 8.331 64.82 hours	303 pyramid frame	3.05 high 4.27 dia (of tripod)	400000	3.8	10.6	Soft-landed on Moon 1967 Sep 11 at 0h 46m 44s. Impact: 1.41°N; 23.18°E
Surveyor 5 rocket	1967-84B 1967 Sep 8.331	2000 cylinder	3.05 dia 9.1 long	-	3.8	10.6	Centaur. In high-eccentricity orbit (period about 11 days)
Surveyor 5 retrorocket	1967-84C 1967 Sep 8.331 64.82 hours	65 sphere (+ nozzle)	0.91 dia 1.32 long	400000	3.8	10.6	Landed on Moon alongside 1967-84A
Surveyor 6	1967-112A 1967 Nov 7.319 65.37 hours	300 pyramid frame	3.05 high 4.27 dia (of tripod)	400000	5.1	10.6	Soft-landed on Moon 1967 Nov 10 at 01h 01m 05s. Impact: 0.49°N; 1.40°W. (Craft made to hop on Nov 17.)
Surveyor 6 rocket	1967-112B 1967 Nov 7.319	2000 cylinder	3.05 dia 9.1 long	-	5.1	10.6	Centaur. In high-eccentricity orbit. Passed 28000 km behind Moon on 1967 Nov 10.63
Surveyor 6 retrorocket	1967-112C 1967 Nov 7.319 65.37 hours	66 sphere (+ nozzle)	0.91 dia 1.32 long	400000	5.1	10.6	Landed on Moon alongside 1967-112A

* Surveyor 4 retrorocket (0.91 m diameter sphere of mass 65 kg) may have exploded before impact.

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D Surveyor 7 1968-01A	1968 Jan 7.271 66.51 hours	306 pyramid frame	3.05 high 4.27 dia (of tripod)	400000	7.1	10.57?	Soft-landed on Moon 1968 Jan 10 at 1h 5m 38s. Impact: 11.45°N; 40.92°S
Surveyor 7 rocket 1968-01B	1968 Jan 7.271	2000 cylinder	3.05 dia 9.1 long	-	7.1	10.57?	Centaur. Passed 20000 km behind Moon on 1968 Jan 10.55. In high-eccentricity orbit
D Surveyor 7 retrorocket 1968-01C	1968 Jan 7.271 66.51 hours	65 sphere + nozzle	0.94 dia 1.32 long	400000	7.1	10.57?	Landed alongside 1968-01A
D Zond 4 1968-13A	1968 Mar 2.77 6.8 days?	5375? sphere- cylinder + 2 paddles?	2.3 dia 5.3 long	400000?	3.5	-	Launched towards 'simulated' Moon. Probably decayed in Earth's atmosphere 1968 Mar 9 at 13h?
Zond 4 rocket 1968-13E	1968 Mar 2.77	cylinder 1900?	3.9 dia 3.9 long?	-	3.5	-	Orbit unknown
Luna 14 rocket 1968-27D	1968 Apr 7.423	cylinder 440	2.0 dia 2.0 long	-	9.4	-	Orbit unknown
D R B Zond 5 (capsule) 1968-76A	1968 Sep 14.897 6.77 days	2760? spheroid	2.2 dia	400000	21.9	11	Passed 1950 km beyond Moon 1968 Sep 18.21. Landed on Earth 1968 Sep 21 at 16h 08m
D Zond 5 (compartment) 1968-76F	1968 Sep 14.897 6.76 days	2615? cylinder + 2 paddles	2.3 dia 3.1 long	400000	21.9	11	Attached to Zond 5 capsule until decay in Earth's atmosphere 1968 Sep 21 at 15h 54m
Zond 5 rocket 1968-76E	1968 Sep 14.897	cylinder 1900?	3.9 dia 3.9 long?	-	21.9	11	Orbit unknown

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D R B Zond 6 (capsule)	1968-101A 1968 Nov 10.800 6.79 days	2760? spheroid	2.2 dia	400000	19.9	11	Passed 2420 km beyond Moon 1968 Nov 14.12. Landed on Earth 1968 Nov 17 at 1. 12m
D Zond 6 (compartment)	1968-101G 1968 Nov 10.800 6.78 days	2615? cylinder + 2 paddles	2.3 dia 3.1 long	400000	19.9	11	Attached to Zond 6 capsule until decay in Earth's atmosphere 1968 Nov 17 at 13h 58m
D Zond 6 rocket	1968-101F 1968 Nov 10.800	cylinder 1900?	3.9 dia 3.9 long?	-	19.9	11	Orbit unknown
D R 3M Apollo 8 (Command module)	1968-1118A 1968 Dec 21.535 6.13 days	5550 cone	3.91 dia 3.66 long	400000	1.7	10.82	Orbited Moon 10 times. Landed on Earth 1968 Dec 27 at 15h 50m
D Apollo 8 (Service module)	1968-1118C 1968 Dec 21.535 6.12 days	22850 then 10100 cylinder + nozzle	3.91 dia 6.70 long	400000	1.7	10.82	Attached to Apollo 8 (CM) until decay in Earth's atmosphere 1968 Dec 27 at 15h 40m
D R 3M Apollo 10 (Command module)	1969-43A 1969 May 18.70 8.00 days	5569 cone	3.91 dia 3.66 long	400000	2.3	10.90?	Orbited Moon 31 times. Landed on Earth 1969 May 26 at 16h 52m
D Apollo 10 (Service module)	1969-43E 1969 May 18.70 8.00 days	23302 (incl. fuel) cylinder	3.91 dia 7.49 long	400000	2.3	10.90?	Attached to 43A until decay in Earth's atmosphere on 1969 May 26 at 16h 42m
LEM 4 (AS + DS)	1969-43C 1969 May 18.70	13993 (incl. fuel) box + octagon	4.09 high 3.76 wide 3.13 deep	-	2.3	-	Ejected from Apollo 10 (CM + SM) into selenocentric orbit. AS now in helio- centric orbit
D Luna 15	1969-58A 1969 Jul 13.121 8.54 days	5600? (incl. fuel) pyramid	3 high 3.2 wide 3.3 deep	400000	28.1	10.90?	Orbited Moon 52 times. Sent crashing into Moon on 1969 Jul 21 at 15h 51m. Impact: near 17°N; 60°E
Luna 15 rocket	1969-58D 1969 Jul 13.121	cylinder 1900?	3.9 dia 3.9 long?	-	28.1	10.90?	Orbit unknown

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D R 3M Apollo 11 (Command module) 1969-59A	1969 Jul 16.564 8.14 days	5557 cone	3.91 dia 3.66 long	400000	2.0	10.83	Orbited Moon 30 times. Landed on Earth 1969 Jul 24 at 16h 50m
D Apollo 11 (Service module) 1969-59E	1969 Jul 16.564 8.13 days	23244 (incl. fuel) cylinder	3.91 dia 7.49 long	400000	2.0	10.83	Attached to 59A until decay in Earth's atmosphere on 1969 Jul 24 at 16h 40m
D LEM 5* (AS + DS) 1969-59C	1969 Jul 16.564 4.29 days	15060 (incl. fuel) Box + octagon	4.09 high 3.76 wide 3.13 deep	400000	2.0	10.83	Soft-landed on Moon 1969 Jul 20 at 20h 17m 42s**. Impact: 0.69°N; 23.43°E. AS relaunched from Moon*
D R Zond 7 (capsule) 1969-67A	1969 Aug 7.995 6.76 days?	2760? spheroid	2.2 dia	400000	24.4	10.90?	Passed 2200 km beyond Moon 1969 Aug 11.18. Landed on Earth 1969 Aug 14 at about 18h 08m?
D Zond 7 (compartment) 1969-67F	1969 Aug 7.995 6.75 days?	2615? cylinder + 2 paddles	2.3 dia 3.1 long	400000	24.4	10.90?	Attached to Zond 7 capsule until decay in Earth's atmosphere 1969 Aug 14 about 17h 54m?
Zond 7 rocket 1969-67E	1969 Aug 7.995	cylinder 1900?	3.9 dia 3.9 long?	-	24.4	10.90?	Orbit unknown
D R 3M Apollo 12 (Command module) 1969-99A	1969 Nov 14.68 10.19 days	5608 cone	3.91 dia 3.66 long	400000	4.8	10.90?	Orbited Moon 45 times. Landed on Earth 1969 Nov 24 at 20h 58m
D Apollo 12 (Service module) 1969-99E	1969 Nov 14.68 10.18 days	23181 (incl. fuel) cylinder	3.91 dia 7.49 long	400000	4.8	10.90?	Attached to 99A until decay in Earth's atmosphere on 1969 Nov 24 at 20h 48m
Apollo 12 rocket 1969-99B	1969 Nov 14.68	13300 cylinder	6.6 dia 18.7 long	862000	4.8	10.90?	Saturn IVB. Passed 5728 km behind Moon 1969 Nov 18.26. In high-eccentricity orbit (period 42 days)
D LEM 6* (AS + DS) 1969-99C	1969 Nov 14.68 4.61 days	15116 (incl. fuel) box + octagon	4.09 high 3.76 wide 3.13 deep	400000	4.8	10.90?	Soft-landed on Moon 1969 Nov 19 at 06h 55m. Impact: 3.20°S; 23.39°W. AS relaunched from Moon*

* See also page 42. ** First manned landing. First step on Moon on 1969 Jul 21 at 02h 56m.

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D R 3M Apollo 13 (Command module)	1970-29A 1970 Apr 11.801 5.95 days	5700 cone	3.91 dia 3.66 long	400000	5.6	10.90?	Passed 250 km beyond Moon 1970 Apr 15.02. Landed on Earth 1970 Apr 17 at 18h 07m
D Apollo 13 (Service module)	1970-29D 1970 Apr 11.801 5.94 days	23190 (incl. fuel) cylinder	3.91 dia 7.49 long	400000	5.6	10.90?	Attached to CM until 1970 Apr 17.55. Decayed in atmosphere 1970 Apr 17 about 17h 57m
D Apollo 13 rocket	1970-29B 1970 Apr 11.801 77.93 hours	13930 cylinder	6.6 dia 18.7 long	400000	5.6	10.90?	Saturn IVB. Hit Moon 1970 Apr 15 at 01h 09m. Impact: 2.4°S; 27.9°W
D LEM 7 (AS + DS)	1970-29C 1970 Apr 11.801 5.94 days	15190 (incl. fuel) Box + octagon	4.09 high 3.76 wide 3.13 deep	400000	5.6	10.90?	Attached to CM until 1970 Apr 17.70. Decayed in atmosphere 1970 Apr 17 about 17h 57m
D R Luna 16 (AS + DS)	1970-72A 1970 Sep 12.560 7.66 days	5600? (incl. fuel) pyramid + cylinder	3.1 high 3.2 wide 3.3 deep	400000	11.6	10.90?	Orbited Moon 41 times? Soft-landed 1970 Sep 20 at 05h 18m. Position: 0.68°S; 56.30°E. AS relaunched from Moon*
Luna 16 rocket	1970-72D 1970 Sep 12.560	cylinder 1900?	3.9 dia 3.9 long?	-	11.6	10.90?	Orbit unknown
D R Zond 8 (capsule)	1970-88A 1970 Oct 20.83 6.75 days	2760? spheroid	2.2 dia	400000	20.2	10.90?	Passed 1120 km beyond Moon 1970 Oct 24.1. Landed on Earth 1970 Oct 27 at 13h 55m
D Zond 8 (compartment)	1970-88D 1970 Oct 20.83 6.74 days	2615? cylinder + 2 paddles	2.3 dia 3.1 long	400000	20.2	10.90?	Attached to Zond 8 capsule until decay in Earth's atmosphere 1970 Oct 27 at 13h 41m
Zond 8 rocket	1970-88C 1970 Oct 20.83	cylinder 1900?	3.9 dia 3.9 long?	-	20.2	10.90?	Orbit unknown

* Landed on Earth 1970 Sep 24 at 05h 26m with Moon soil (see page 42).

(R) Orbits in the Earth-Moon system (continued)

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Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D Luna 17 (with Lunokhod 1*)	1970 Nov 10.614 6.54 days	5600? (incl. fuel) pyramid + car	2.3 high 3.2 wide 3.3 deep	400000	11.3	10.90?	Orbited Moon 28 times. Soft-landed 1970 Nov 17 at 03h 47m. Position: 38.28°N; 35°W
Luna 17 rocket	1970 Nov 10.614	1900? cylinder	3.9 dia 3.9 long?	-	11.3	10.90?	Orbit unknown
D R 3M Apollo 14 (Command module)	1971 Jan 31.878 9.00 days	5758 cone	3.91 dia 3.66 long	400000	4.9	10.90?	Orbited Moon 34 times. Landed on Earth 1971 Feb 9 at 21h 05m
D Apollo 14 (Service module)	1971 Jan 31.878 8.99 days	23471 (incl. fuel) cylinder	3.91 dia 7.49 long	400000	4.9	10.90?	Attached to CM until decay in Earth's atmosphere on 1971 Feb 9 at 20h 55m
D Apollo 14 rocket	1971 Jan 31.878 82.6 hours	13990 cylinder	6.6 dia 18.7 long	400000	4.9	10.90?	Saturn IVB. Hit Moon 1971 Feb 4 at 07h 41m. Impact: 8.0°S; 26.6°W
D T? LEM 8 (AS + DS)	1971 Jan 31.878 4.51 days	15277 (incl. fuel) box + octagon	4.09 high 3.76 wide 3.13 deep	400000	4.9	10.90?	Soft-landed on Moon 1971 Feb 5 at 09h 18m. Impact: 3.67°S; 17.49°W. AS relaunched from Moon**

* Lunokhod 1 is a 756 kg roving vehicle; 1.45 m high, 2.15 m wide, 2.22 m long.

** See page 42.

(B) Orbits in the Earth-Moon system (continued)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D R 3M Apollo 15 (Command module)	1971 Jul 26.565 12.30 days	5820 cone	3.91 dia 3.66 long	400000	4.2	10.90?	Orbited Moon 74 times. Landed on Earth 1971 Aug 7 at 20h 46m
D Apollo 15 (Service module)	1971 Jul 26.565 12.29 days	24520 (incl. fuel) cylinder	3.91 dia 7.49 long	400000	4.2	10.90?	Attached to CM until decay in Earth's atmosphere on 1971 Aug 7 at 20h 36m
D Apollo 15 rocket	1971 Jul 26.565 79.40 hours	13990 cylinder	6.6 dia 18.7 long	400000	4.2	10.90?	Saturn IVB. Hit Moon 1971 Jul 29 at 20h 58m 42s. Impact: 1.0°S; 11.87°W
D T? LEM 10 (AS + DS) (with LRV-1*)	1971 Jul 26.565 4.36 days	16434 (incl. fuel) box + octagon	4.09 high 3.76 wide 3.13 deep	400000	4.2	10.90?	Soft-landed on Moon 1971 Jul 30 at 22h 16m. Impact: 26.08°N; 3.66°E. AS relaunched from Moon**
D Luna 18 [†] (AS + DS?)	1971 Sep 2.570 8.75 days	5600? (incl. fuel) pyramid + cylinder	3.1 high? 3.2 wide 3.3 deep	400000	12.6	10.90?	Orbited Moon 54 times. Hit Moon 1971 Sep 11 at 07h 48m. Impact: 3.57°N; 56.5°E
Luna 18 rocket	1971 Sep 2.570	1900? cylinder	3.9 dia 3.9 long?	-	12.6	10.90?	Orbit unknown
Luna 19 rocket	1971 Sep 28.42	1900? cylinder	3.9 dia 3.9 long?	-	8.8	10.90?	Orbit unknown

* Lunar roving vehicle, mass 213 kg; 1.14 m high, 2.29 m wide, 3.10 m long.

† Damage on landing prevented re-launch of ascent stage.

** See page 42.

(B) Orbits in the Earth-Moon system (continued)

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Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D K 3M Luna 20 (AS + DS)	1972-07A 1972 Feb 14.14 7.66 days	5600? (incl. fuel) pyramid + cylinder	3.1 high 3.2 wide 3.3 deep	400000	28.7	10.90?	Orbited Moon 40 times? Soft-landed 1972 Feb 21 at 19h 19m. Position: 3.53°N; 56.55°E. AS relaunched from Moon*
Luna 20 rocket	1972-07B 1972 Feb 14.14	1900? cylinder	3.9 dia 3.9 long?	-	28.7	10.90?	Orbit unknown
D R 3M Apollo 16 (Command module)	1972-31A 1972 Apr 16.75 11.07 days	5840 cone	3.91 dia 3.66 long	400000	2.9	10.90?	Orbited Moon 64 times. Landed on Earth 1972 Apr 27 at 19h 45m
D Apollo 16 (Service module)	1972-31F 1972 Apr 16.75 11.06 days	24518 (incl. fuel) cylinder	3.91 dia 7.49 long	400000	2.9	10.90?	Attached to CM until decay in Earth's atmosphere on 1972 Apr 27 at 19h 35m
D Apollo 16 rocket	1972-31B 1972 Apr 16.75 75.2 hours?	13970 cylinder	6.6 dia 18.7 long	400000	2.9	10.90?	Saturn IVB. Hit Moon 1972 Apr 19 at 21h 07m? Impact: 1.83°N; 23.30°W
D T LEM 11 (AS + DS) (with LRV-2)	1972-31C 1972 Apr 16.75 4.35 days	16438 (incl. fuel) box + octagon	4.09 high 3.76 wide 3.13 deep	400000	2.9	10.90?	Soft-landed on Moon 1972 Apr 21 at 02h 24m. Impact: 8.99°S; 15.51°E. AS relaunched from Moon*.
D Particles and Fields Subsatellite 2	1972-31D 1972 Apr 16.75 43.2 days	38 hexagonal cylinder	0.36 dia 0.79 long	400000	2.9	10.90?	Decayed naturally after 425 Mo. orbits 1972 May 29 at 23h. Impact: 10.16°N; 111.94°E

* See page 43.

(B) Orbits in the Earth-Moon system (continued)

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Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D R 3M Apollo 17 (Command module)	1972-96A 1972 Dec 7.23 12.58 days	5826 cone	3.91 dia 3.66 long	400000	1.4	10.90?	Orbited Moon 75 times. Landed on Earth 1972 Dec 19 at 19h 24m
D Apollo 17 (Service module)	1972-96E 1972 Dec 7.23 12.57 days	24514 full cylinder	3.91 dia 7.49 long	400000	1.4	10.90?	Attached to CM until decay in Earth's atmosphere on 1972 Dec 19 at 19h 14m
D Apollo 17 rocket	1972-96B 1972 Dec 7.23 87.0 hours?	13930 cylinder	6.6 dia 18.7 long	400000	1.4	10.90?	Saturn IVB. Hit Moon 1972 Dec 10 at 20h 33m? Impact: 4.2°S; 12.3°W
D T LEM 12 (AS + DS) (with LRV-3)	1972-96C 1972 Dec 7.23 4.60 days	16440 full box + octagon	4.09 high 3.76 wide 3.13 deep	400000	1.4	10.90?	Soft-landed on Moon 1972 Dec 11 at 19h 55m. Site: 20.16°N; 30.75°E. AS relaunched from Moon*
D Luna 21 (with Lunokhod 2**)	1973-01A 1973 Jan 8.288 7.65 days	5600? full pyramid + car	2.3 high 3.2 wide 3.3 deep	400000	3.6	10.90?	Orbited Moon 40 times. Soft-landed 1973 Jan 15 at 22h 35m. Position: 26.5°N; 30.6°E
Luna 21 rocket	1973-01D 1973 Jan 8.288	1900? cylinder	3.9 dia 3.9 long?	-	3.6	10.90?	Orbit unknown. Proton escape stage
D Explorer 49 third stage	1973-39B 1973 Jun 10.592 5 years?	66 sphere + nozzle	0.94 dia 1.32 long	390250	9.4	10.90?	Burner 2. In high-eccentricity orbit
Luna 22 rocket	1974-37E 1974 May 29.373	1900? cylinder	3.9 dia 3.9 long?	-	7.5	10.90?	Orbit unknown. Proton escape stage

* See page 43.

** Lunokhod 2 mass 840 kg.

(B) Orbits in the Earth-Moon system (concluded)

Name	Launch date (UT) and flight time	Mass (kg) and basic shape	Basic size (m)	Maximum distance from Earth (km)	Moon's age at launch (days)	All-burnt velocity km/s	Remarks
D Luna 23* (AS + DS)	1974 Oct 28.60 8.63 days	5600? full pyramid + cylinder	3.1 high 3.2 wide 3.3 deep	400000	13.1	10.90?	Orbited Moon 53 times? Hard-landed 1974 Nov 6 at 05h 37m. Position: 13.5°N; 56.5°E?
Luna 23 rocket	1974 Oct 28.60	1900? cylinder	3.9 dia 3.9 long?	-	13.1	10.90?	Orbit unknown. Proton escape stage
D Luna 24 (AS + DS)	1976 Aug 9.628 8.65 days	5600? full pyramid + cylinder	3.1 high 3.2 wide 3.3 deep	400000	13.6	10.90?	Orbited Moon 53 times? Soft-landed 1976 Aug 18 at 06h 36m. Position: 12.75°N; 62.2°E. AS relaunched from Moon**
Luna 24 rocket	1976 Aug 9.628	1900? cylinder	3.9 dia 3.9 long?	-	13.6	10.90?	Orbit unknown. Proton escape stage

* Damage on landing prevented re-launch of ascent stage.

** See page 43.

(C) Orbits around the Moon - Earth launch

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Name	Launch date; injection date; ejection or landing date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselenic height (km)	Aposelenic height (km)	Orbital eccen- tricity
Luna 10	1966-27A 1966 Mar 31.449 1966 Apr 3.78	245 cylinder	0.6 dia 1.0 long	1966 Apr 3.78 1966 May 3 1966 May 30	71.90 72.01 72.03	178.25 178.27 178.05	2421 2422 2420	350 361 379	1017 1007 985	0.138 0.134 0.125
Luna 10 retrorocket	1966 Mar 31.449 1966 Apr 3.78	1355 (incl. fuel) cylinder	0.9 dia 1.7 long		Orbit similar to 1966-27A					
Lunar Orbiter 1	1966-73A 1966 Aug 10.810 1966 Aug 14.66 1966 Oct 29.81 ^a	386 truncated cone	1.52 dia 1.68 high	1966 Aug 14.66 1966 Aug 21.41 1966 Aug 25.67	12.14 12.08 12.3	217.58 209.25 206	2765 2694 2669	203 53 40	1851 1858 1818	0.298 0.335 0.334
Luna 11	1966-78A 1966 Aug 24.34 1966 Aug 27.909	1640 (incl. fuel) cylinder	1.0 dia? 2.7 long?	1966 Aug 27.91	27	178	2418	160	1200	0.215
Luna 12	1966-94A 1966 Oct 22.37 1966 Oct 25.87	1620 fuelled 1136 empty cone-cylinder	1.0 dia? 2.7 long?	1966 Oct 25.87	0.0	205	2658	100	1740	0.309
Lunar Orbiter 2	1966-100A 1966 Nov 6.973 1966 Nov 10.85 1967 Oct 11.30 ^a	389 truncated cone	1.52 dia 1.68 high	1966 Nov 10.85 1966 Nov 15.96 1966 Dec 8.86 1966 Dec 8.86	11.8 11.8 11.8 17.6	217 208 208 210	2757 2686 2686 2702	192 50 39 43	1846 1845 1858 1886	0.300 0.334 0.339 0.341
Lunar Orbiter 3	1967-08A 1967 Feb 5.053 1967 Feb 8.913 1967 Oct 9.436 ^a	389 truncated cone	1.52 dia 1.68 high	1967 Feb 8.91 1967 Feb 12.76 1967 Aug 30.82	21 20.93 20.9	216 208 131	2740 2687 1968	216 55 144	1791 1844 316	0.287 0.333 0.044
Lunar Orbiter 4	1967-41A 1967 May 4.934 1967 May 8.637 1967 Oct 6.5 ^a	390.1 truncated cone	1.52 dia 1.68 high	1967 May 8.64 1967 Jun 8.94	85.48 84.4	720 344	6090 3748	2700 77	6000 3943	0.27 0.516
Explorer 35* (Imp 6)	1967-70A 1967 Jul 19.60 1967 Jul 22.6	104.5 octagonal cylinder	0.71 dia 0.86 long	1967 Jul 22.6 1967 Dec 8.5 1971 Aug 16.5	147.3 143.9 166.0	710 692 691.5	6063 5980 5980	764 784 809	7886 7700 7675	0.587 0.58 0.574
Lunar Orbiter 5	1967-75A 1967 Aug 1.940 1967 Aug 5.703 1968 Jan 31.332 ^a	390 truncated cone	1.52 dia 1.68 high	1967 Aug 5.70 1967 Aug 7.36 1967 Oct 10.82	85.0 84.6 85.15	506 498 225.29	4860 4810 2831	196 100 200	6040 6050 1986	0.60 0.62 0.315

* A retrorocket, 1967-70D, of mass 36 kg, separated from 70A on Jul 22.7. ^a Impact date.
See pages 24-26 for further details of spacecraft marked with D.

(C) Orbits around the Moon - Earth launch (continued)

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Name	Launch date; injection date; ejection or landing date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselene height (km)	Aposelene height (km)	Orbital eccen- tricity
Luna 14	1968 Apr 7.423 1968 Apr 10.809	1700? (incl. fuel) cone-cylinder	1.0 dia? 2.7 long?	1968 Apr 10.81	42.0	160	2250	160	870	0.158
D 3M Apollo 8 (CM + SM)	1968 Dec 21.535 1968 Dec 24.42 1968 Dec 25.25	20940 then 20550 cone-cylinder	3.91 dia 10.36 long	1968 Dec 24.42 1969 Dec 24.60	168 168	128 120	1950 1852	112 113	313 115	0.052 0.0005
D 3M Apollo 10 (CM + SM)	1969 May 18.70 1969 May 21.87 1969 May 24.42	28870 (incl. fuel) cone-cylinder	3.91 dia 11.15 long	1969 May 21.87 1969 May 22.05	174.4 174.4	128 120	1950 1850	111 107	316 115	0.053 0.002
LEM 4 descent stage	1969 May 18.70 1969 May 21.87	2133 (empty) octagon + cone	3.13 dia 1.57 long	1969 May 22.80 1969 May 22.89 1969 May 22.98	174.4 174.4 174.4	120 115 126	1850 1803 1925	107 16 22	115 113 352	0.002 0.027 0.086
LEM 4 ascent stage [†]	1969 May 18.70 1969 May 21.87 1969 May 23.26	2170 (empty) box + 2 tanks	2.52 high 3.76 wide 3.13 deep	1969 May 22.98 1969 May 23.02 1969 May 23.08	174.4 174.4 174.4	114 117 117	1792 1820 1818	20 77 28	87 88 131	0.019 0.003 0.028
D Luna 15	1969 Jul 13.121 1969 Jul 17.42 1969 Jul 21.66 ^g	4000? (incl. fuel) pyramid	3 high 3.2 wide 3.3 deep	1969 Jul 17.42 1969 Jul 19.55 1969 Jul 20.59	126 126 127	166 123.5 114	2300 1900 1800	240 95 16	870 222 110	0.14 0.03 0.03
D 3M Apollo 11 (CM + SM)	1969 Jul 16.564 1969 Jul 19.724 1969 Jul 22.21	28800 (incl. fuel) cone-cylinder	3.91 dia 11.15 long	1969 Jul 19.72 1969 Jul 19.91	178.75 178.75	128 120	1950 1850	113 100	313 122	0.051 0.006
D LEM 5 (AS + DS)	1969 Jul 16.564 1969 Jul 19.724 1969 Jul 20.85 ^g	4213 (empty) box + octagon	4.09 high 3.76 wide 3.13 deep	1969 Jul 20.74 1969 Jul 20.84	178.7 178.7	120 114	1850 1800	100 14	122 108	0.006 0.026
D 3M Apollo 12 (CM + SM)	1969 Nov 14.68 1969 Nov 18.16 1969 Nov 21.87	28790 (incl. fuel) cone-cylinder	3.91 dia 11.15 long	1969 Nov 18.16 1969 Nov 18.34	164.7 164.7	128 120	1950 1850	111 100	314 122	0.052 0.006
D LEM 6 (AS + DS)	1969 Nov 14.68 1969 Nov 18.16 1969 Nov 19.29 ^g	4370 (empty) box + octagon	4.09 high 3.76 wide 3.13 deep	1969 Nov 19.18 1969 Nov 19.24	164.7 164.7	120 114	1850 1800	100 14	122 111	0.006 0.027

See pages 28-29 for further details of spacecraft marked with D.

^g Impact or landing date.[†] The only Moon satellite to be re-fired into heliocentric orbit (page 12).

(C) Orbits around the Moon - Earth launch (continued)

Name	Launch date; injection date; ejection or landing date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselene height (km)	Aposelene height (km)	Orbital eccen- tricity
D R Luna 16 (AS + DS)	1970 Sep 12.560	4000? fuelled	3.1 high	1970 Sep 17	70	119	1848	110	110	0
	1970 Sep 16.86	1880 empty	3.2 wide	1970 Sep 20.21	71	114	1798	15	106	0.025
	1970 Sep 20.22 ^a	pyramid + cylinder	3.3 deep							
D Luna 17 (with Lunokhod 1)	1970 Nov 10.614	4000? fuelled	2.3 high	1970 Nov 15	141	116	1823	85	85	0
	1970 Nov 14.91	1836 landed	3.2 wide	1970 Nov 17.15	141	114	1790	19	85	0.018
	1970 Nov 17.158 ^a	pyramid + car	3.3 deep							
D 3M Apollo 14 (CM + SM)	1971 Jan 31.878	29229	3.91 dia	1971 Feb 4.29	166	128.5	1950	109	315	0.053
	1971 Feb 4.29	(incl. fuel)	11.15 long	1971 Feb 4.47	166	114.0	1801	16	110	0.026
	1971 Feb 7.07	cone-cylinder		1971 Feb 5.24	166	118.4	1847	104	114	0.003
D LEM 8 (AS + DS)	1971 Jan 31.878	4267 (empty)	4.09 high	1971 Feb 5.20	166	114.0	1801	16	110	0.026
	1971 Feb 4.29	Box + octagon	3.76 wide							
	1971 Feb 5.39 ^a		3.13 deep							
D 3M Apollo 15 (CM + SM)	1971 Jul 26.565	30340	3.91 dia	1971 Jul 29.84	151.28	128	1949	108	314	0.053
	1971 Jul 29.84	(incl. fuel)	11.15 long	1971 Jul 30.01	151.28	114	1800	15	109	0.026
	1971 Aug 4.89	cone-cylinder		1971 Aug 2.45	151.28	120	1851	103	123	0.006
D LEM 10 (with LRV-1)	1971 Jul 26.57	4930 (empty)	4.09 high	1971 Jul 30.74	151.28	120	1858	100	141	0.011
	1971 Jul 29.84	box + octagon	3.76 wide							
	1971 Jul 30.93 ^a		3.13 deep							
D Particles and Fields Subsatellite 1	1971 Jul 26.57	35	0.36 dia	1971 Aug 4.83	151.28	119.75	1858	103	136	0.009
	1971 Jul 29.84	hexagonal cylinder	0.79 long	1972 Sep 1.00	151.41	119.71	1857	52	186	0.036

See pages 30-32 for further details of spacecraft marked with D. ^a Landing date.

(C) Orbits around the Moon - Earth launch (continued)

Page 39

Name	Launch date; injection date; ejection or landing date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselene height (km)	Aposelene height (km)	Orbital eccen- tricity
D Luna 18 (AS + DS?)	1971 Sep 2.57 1971 Sep 6.87 1971 Sep 11.32 ^a	4000? fuelled pyramid + cylinder	3.1 high? 3.2 wide 3.3 deep	1971 Sep 7 1971 Sep 11.31	35 35	119 114	1839 1797	101 18	101 100	0 0.023*
Fragment 1971-73B										
Luna 19	1971 Sep 28.42 1971 Oct 2.72	4000? pyramid	2.3 high 3.2 wide 3.3 deep	1971 Oct 3 1971 Oct 6 1971 Nov 28	40.58 40.58 40.68	121.75 121.00 131	1878 1869 1969	140 127 77	140 135 385	0 0.002 0.078
Fragment 1971-82C										
D Luna 20 (AS + DS)	1972 Feb 14.14 1972 Feb 18.51 1972 Feb 21.80 ^a	4000? fuelled 1880 landed pyramid + cylinder	3.1 high 3.2 wide 3.3 deep	1972 Feb 18.51 1972 Feb 19	65 65	118 114	1838 1799	100 21	100 160	0 0.022
D Apollo 16 (CM + SM)	1972 Apr 16.75 1972 Apr 19.85 1972 Apr 25.09	30358 (incl. fuel) cone-cylinder	3.91 dia 11.15 long	1972 Apr 19.85 1972 Apr 20.01 1972 Apr 21.05	169.3 169.3 169.3	128 114 120	1949 1796 1850	107 20 98	315 96 126	0.053 0.021 0.008
D LEM 11 (with LRV-2)	1972 Apr 16.75 1972 Apr 19.85 1972 Apr 21.10 ^a	4893 (empty) box + octagon	4.09 high 3.76 wide 3.13 deep	1972 Apr 20.76	169.3	114	1796	20	96	0.021
D Particles and Fields Subsatellite 2	1972 Apr 16.75 1972 Apr 19.85 1972 May 29.96 ^a	38 hexagonal cylinder	0.36 dia 0.79 long	1972 Apr 24.89 1972 May 29.27	169.28 169.28	119.0 119.0	1848 1848	91 4	130 217	0.011 0.058

* Approximate orbit.

^a Impact or landing date.

See pages 32 and 33 for further details of spacecraft marked with D.

(C) Orbits around the Moon - Earth launch (continued)

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Name	Launch date: injection date; ejection or landing date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselene height (km)	Apiselene height (km)	Orbital eccen- tricity
D 3M Apollo 17 (CM + SM)	1972 Dec 7.23 1972 Dec 10.83 1972 Dec 16.98	30340 full cone-cylinder	3.91 dia 11.15 long	1972 Dec 10.83 1972 Dec 11.01 1972 Dec 11.78	159.9 159.9 159.9	128 115 118.8	1944 1807 1849	94 28 96	317 109 126	0.057 0.023 0.008
D LEM 12 (with LRV-3)	1972 Dec 7.23 1972 Dec 10.83 1972 Dec 11.83 ^a	4937 empty box + octagon	4.09 high 3.76 wide 3.13 deep	1972 Dec 11.72 1972 Dec 11.79	159.9 159.9	115 114	1807 1800	28 13	109 111	0.023 0.027
D Luna 21 (with Lunokhod 2)	1973 Jan 8.288 1973 Jan 12.60 1973 Jan 15.94 ^a	4000? full pyramid + car	2.3 high 3.2 wide 3.3 deep	1973 Jan 12.60 1973 Jan 15.93	60 60	118 114	1838 1801	90 16	110 110	0.005 0.026
Explorer 49 (RAE 2)	1973 Jun 10.592 1973 Jun 15.26	200 cylinder + booms	0.92 dia 0.79 long	1973 Jun 15.31 1973 Jun 20.16 1974 Aug 14 1975 Sep 1.0	38.26 38.71 55.34 76.2	241 221.2 221.9 222.0	2964 2797 2802 2803	1120 1053 1051 1020	1331 1065 1077 1109	0.036 0.002 0.005 0.016
Explorer 49 retrorocket	1973 Jun 10.592 1973 Jun 15.26	134 full cone-cylinder	0.5 dia? 1.0 long?	Orbit similar to 1973-39A						
Fragment	1973-39G									
Luna 22	1974 May 29.373 1974 Jun 2.68?	4000? pyramid	2.3 high 3.2 wide 3.3 deep	1974 Jun 2.7 1974 Jun 9 1974 Jun 13 1974 Nov 11.63 1975 Apr 2.33 1975 Aug 24 1975 Sep 3.4*	19.58 19.58 19.58 19.55 21 21 21	130 121 131 192 192 192 179	1958 1873 1978 2542 2543 2542 2431	219 25 181 171 200 30 100	221 244 299 1437 1409 1578 1286	0.0 0.058 0.030 0.248 0.238 0.304 0.244

See page 34 for further details of spacecraft marked with D. ^a Landing date.

* Manoeuvring fuel exhausted on 1975 Sep 2.

(C) Orbits around the Moon - Earth launch (concluded)

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Name	Launch date: injection or ejection or landing date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselene height (km)	Aposelene height (km)	Orbital eccen- tricity
D Luna 23 (AS + DS)	1974-84A 1974 Oct 28.60 1974 Nov 1.912 1974 Nov 6.23 ^⓪	4000? full pyramid + cylinder	3.1 high 3.2 wide 3.3 deep	1974 Nov 2 1974 Nov 6.22	138 138	117 114	1837 1799	94 17	104 105	0.003 0.024
D Luna 24 (AS + DS)	1976-81A 1976 Aug 9.628 1976 Aug 13.966 1976 Aug 18.275 ^⓪	4000? full pyramid + cylinder	3.1 high 3.2 wide 3.3 deep	1976 Aug 14.0 1976 Aug 17	120 120	119 114	1853 1804	115 12	115 120	0 0.030

^⓪ Landing date. See page 35 for further details.

(D) Orbits around the Moon - Moon launch

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	Name	Moon launch date; descent date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselene height (km)	Aposelene height (km)	Orbital eccen- tricity
2M	LEM 5* ascent stage	1969 Jul 21.75	2179 (empty) box + 2 tanks	2.52 high 3.76 wide 3.13 deep	1969 Jul 21.76 1969 Jul 21.79 1969 Jul 21.86 1969 Jul 21.90	178.7 178.7 178.7 178.7	114 117 119 120	1789 1822 1836 1848	17 82 81 109	86 86 115 111	0.019 0.001 0.009 0.0003
D 2M	LEM 6** ascent stage	1969 Nov 20.60 1969 Nov 20.93	2159 (empty) box + 2 tanks	2.52 high 3.76 wide 3.13 deep	1969 Nov 20.61 1969 Nov 20.64 1969 Nov 20.71 1969 Nov 20.75	165.6 165.6 165.6 165.6	114 117 119 120	1789 1822 1836 1848	17 82 81 109	86 86 115 111	0.019 0.001 0.009 0.0003
D R	Luna 16 ascent stage	1970 Sep 21.32 1970 Sep 24.23	800? (incl. fuel) cylinder + 3 spheres	2.3 high 1.6 wide 0.5 deep	Reached Moon escape velocity Landed on Earth 1970 Sep 24.23 with Moon soil						
D 2M	LEM 8*** ascent stage	1971 Feb 6.78 1971 Feb 7.03	2128 (empty) box + 2 tanks	2.52 high 3.76 wide 3.13 deep	1971 Feb 6.79 1971 Feb 6.86	166 166	114 118.4	1794 1847	17 104	94 114	0.022 0.003
D 2M	LEM 10† ascent stage	1971 Aug 2.72 1971 Aug 3.13	2127 (empty) box + 2 tanks	2.52 high 3.76 wide 3.13 deep	1971 Aug 2.73 1971 Aug 2.80	151.28 151.28	114 120	1784 1851	17 103	75 123	0.017 0.006

* Briefly docked with Apollo 11 for crew transfer on 1969 Jul 21.90. Still in orbit.

** Briefly docked with Apollo 12 for crew transfer on 1969 Nov 20.75. Sent crashing into Moon: 5.5°S, 23.4°W.

*** Briefly docked with Apollo 14 for crew transfer on 1971 Feb 6.86. Sent crashing into Moon: 3.50°S, 19.27°W.

† Briefly docked with Apollo 15 for crew transfer on 1971 Aug 2.80. Sent crashing into Moon: 26.35°N, 0.25°E.

(D) Orbits around the Moon - Moon launch (concluded)

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	Name	Moon launch date; descent date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Moon's equator (deg)	Period (min)	Semi major axis (km)	Periselene height (km)	Aposelene height (km)	Orbital eccentricity
D R	Luna 20 ascent stage	1972 Feb 22.96 1972 Feb 25.80	800? full cylinder + 3 spheres	2.3 high 1.6 wide 0.5 deep							
2M	LEM 11* ascent stage	1972 Apr 24.06	2134 empty box + 2 tanks	2.52 high 3.76 wide 3.13 deep	1972 Apr 24.07 1972 Apr 24.14	169.3 169.3	114 120	1784 1850	17 98	75 126	0.017 0.008
D 2M	LEM 12** ascent stage	1972 Dec 14.96 1972 Dec 15.29	2145 empty box + 2 tanks	2.52 high 3.76 wide 3.13 deep	1972 Dec 14.97 1972 Dec 15.04	159.9 159.9	114 118.8	1784 1849	17 96	75 126	0.017 0.008
D R	Luna 24 ascent stage	1976 Aug 19.226 1976 Aug 22.747	800? full cylinder + 3 spheres	2.3 high 1.6 wide 0.5 deep							

* Briefly docked with Apollo 16 for crew transfer on 1972 Apr 24.14. Still in orbit.

** Briefly docked with Apollo 17 for crew transfer on 1972 Dec 15.04. Sent crashing into Moon: 19.95°N, 30.73°E.

(E) Orbits around Mars - Earth launch

Name	Launch date; injection date; ejection date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Mars equator (deg)	Period (min)	Semi major axis (km)	Periapsis height (km)	Apoapsis height (km)	Orbital eccen- tricity
Mars 2 orbiter	1971-45A 1971 May 19.68 1971 Nov 27.85	3440? full 2060? empty cylinder + 2 panels	2.3 dia 2.7 long	1971 Nov 27.85	48.9	1078	16585	1380	25000	0.712
D Mars 2 lander	1971-45E 1971 May 19.68	1200? full 635 empty cone-sphere	2.5 dia 1.1 long	Sent onto impact path 1971 Nov 27.66 Hard-landed at 44°S, 47°E						
Mars 3 orbiter	1971-49A 1971 May 28.64 1971 Dec 2.57	3440? full 2060? empty cylinder + 2 panels	2.3 dia 2.7 long	1971 Dec 2.57	48.9?	15840	59495	1500	190700	0.951
D Mars 3 [†] lander	1971-49F 1971 May 28.64	1200? full 635 empty cone-sphere	2.5 dia 1.1 long	Sent onto impact path 1971 Dec 2.38 Soft-landed at 45°S, 158°W						
Mariner 9	1971-51A 1971 May 30.93 1971 Nov 14.02	520 empty octagon + 2 tanks	1.38 dia 2.29 long	1971 Nov 14.02 1971 Nov 16.12 1971 Dec 30	64.28 64.36 64.36	754 718 719	13051 12666 12679	1397 1397 1653	17916 17145 16915	0.633 0.622 0.602
Mars 5 orbiter	1973-49A 1973 Jul 25.79 1974 Feb 12.66	3440? full 2060? empty box + 2 vanes	2.3 dia 2.7 long	1974 Feb 12.66	35.0	1493	20525	1760	32500	0.749
Viking 1 orbiter	1975-75A 1975 Aug 20.89 1976 Jun 19	2325 full 950? empty box + 4 vanes	3.3 high 1.8 wide 1.5 deep	1976 Jun 19 1976 Jun 21 1979 Jul 20	37.8? 37.8 39.9	2544 1476 1487	29445 20444 20545	1500 1514 357	50600 32583 33943	0.834 0.760* 0.817
D Viking 1 lander	1975-75C 1975 Aug 20.89 1976 Jun 19 1976 Jul 20.51	1090 full 600 empty pyramid	2.1 high 3.0 wide 2.5 deep	1976 Jun 21	37.8	1476	20444	1514	32583	0.760
Separated from Orbiter 1976 Jul 20.37 Soft-landed at 22.27°N, 47.94°W										

* 88 km flyby of Phobos on 20 Feb 1977. Transmissions ceased July-Aug 1980 when attitude control gas was exhausted.

† Surface transmissions lasted 20 seconds.

(E) Orbits around Mars - Earth launch (concluded)

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Name	Launch date; injection date; ejection date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Mars equator (deg)	Period (min)	Semi major axis (km)	Periapsis height (km)	Apoapsis height (km)	Orbital eccen- tricity
Viking 2* orbiter	1975 Sep 9.78	2325 full 9507 empty box + 4 vanes	3.3 high 1.8 wide 1.5 deep	1976 Aug 7.47	55.6	1644.6	22011	1502	35728	0.778
	1976 Aug 7.47			1976 Aug 25.76	55.6	1438.8	20132	1432	32042	0.760
				1976 Aug 27	55.4**	1477.8	20492	1502	32692	0.761
				1976 Dec 20	80	1590	21520	787	35463	0.806
Viking 2† lander		1090 full 600 empty pyramid	2.1 high 3.0 wide 2.5 deep	1977 Oct 23	80.3	1439	20134	302	33176	0.816
	1975 Sep 9.78			1976 Aug 27	55.4	1477.8	20492	1502	32692	0.761
	1976 Aug 7.47					Separated from Orbiter 1976 Sep 3.82				
	1976 Sep 3.96					Soft-landed at 47.67°N, 225.71°W				

* Passed 23 km from Deimos on 1977 Oct 15. Transmissions ceased on 1978 Jul 24 when attitude control gas exhausted.

** Orbital inclination changed to 75 deg on 1976 Sep 30, after manoeuvre.

† Transmissions ceased during March 1980.

(F) Orbits round Venus - Earth launch

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Name	Launch injection date	Mass (kg) and basic shape	Basic size (m)	Date of orbital determination (UT)	Inclination to Venus equator (deg)	Period (min)	Semi major axis (km)	Periapsis height (km)	Apoapsis height (km)	Orbital eccen- tricity
Venus 9 orbiter	1975-50A 1975 Jun 8.11 1975 Oct 22.17	3376 full cylinder + 2 panels	2.3 dia 2.7 long 5.7 span	1975 Oct 22.17	34.17	2898	62910	1510	112200	0.879
Venus 10 orbiter	1975-54A 1975 Jun 14.13 1975 Oct 25.17	3473 full cylinder + 2 panels	2.3 dia 2.7 long 5.7 span	1975 Oct 25.17	29.50	2963	63810	1620	113900	0.880
Pioneer Venus orbiter	1978-51A 1978 May 20.55 1978 Dec 4.665	580 full 370 empty cylinder	2.4 dia 1.2 long	1978 Dec 4.67 1978 Dec 6.83	105 105	1391.4 1454	38564 39160	378 233*	64645 65983	0.833 0.839

* Periapsis height was reduced by manoeuvres to 149 km by 1 Jan 1979.

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USA	Apollo 8	1968-118	11	28	37	-
"	" 9	1969-18	12	-	-	-
"	" 10	1969-43	12	28	37	-
"	" 11	1969-59	12	29	37	-
"	" 12	1969-99	-	29	37	-
"	" 13	1970-29	-	30	-	-
"	" 14	1971-08	-	31	38	-
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"	" 16	1972-31	-	33	39	-
"	" 17	1972-96	-	34	40	-
"	Apollo 15 subsatellite	1971-63	-	-	38	-
"	" 16 "	1972-31	-	33	39	-
"	Apollo - see also LEM					
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FRG	Helios 1	1974-97	16	-	-	-
"	" 2	1976-03	18	-	-	-
USA	IMP 6 - see Explorer 35					
"	ISEE 3	1978-79	20	-	-	-
"	LEM 4	1969-43	12	28	37	-
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"	LEM - see also Apollo					
"	LRV 1 - see LEM 10					
"	LRV 2 - see LEM 11					
"	LRV 3 - see LEM 12					
USSR	Luna 1	1959μ	7	-	-	-
"	" 2	1959ξ	-	21	-	-
"	" 3	1959θ	-	21	-	-
"	" 4	1963-08	-	21	-	-
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"	" 2	1966-100	-	24	36	-
"	" 3	1967-08	-	25	36	-
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"	" 5	1967-75	-	26	36	-
USSR	Lunokhod 1 - see Luna 17					
"	" 2 - see Luna 21					
USA	Mariner 2	1962ap	8	-	-	-
"	" 3	1964-73	8	-	-	-
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"	" 5	1973-49	15	-	-	44
"	" 6	1973-52	15	-	-	-
"	" 7	1973-53	15 & 16	-	-	-
"	Mechta - see Luna 1					
USA	Pioneer 1	1958n	-	21	-	-
"	" 3	1958o	-	21	-	-
"	" 4	1959v	7	-	-	-
"	" 5	1960a	7	-	-	-
"	" 6	1965-105	10	-	-	-
"	" 7	1966-75	10	-	-	-
"	" 8	1967-123	11	-	-	-
"	" 9	1968-100	11	-	-	-
"	" 10	1972-12	14	-	-	-
"	" 11	1973-19	14	-	-	-
"	Pioneer Venus Orbiter	1978-51	19	-	-	46
"	Pioneer Multiprobe	1978-78	19	-	-	-
"	RAE 2 - see Explorer 49					
"	Ranger 3	1962a	7	-	-	-
"	" 4	1962u	-	21	-	-
"	" 5	1962bn	8	-	-	-
"	" 6	1964-07	-	22	-	-
"	" 7	1964-41	-	22	-	-
"	" 8	1965-10	-	22	-	-
"	" 9	1965-23	-	22	-	-
"	Surveyor 1	1966-45	-	24	-	-
"	" 2	1966-84	-	24	-	-
"	" 3	1967-35	-	25	-	-
"	" 4	1967-68	-	26	-	-
"	" 5	1967-84	-	26	-	-
"	" 6	1967-112	-	26	-	-
"	" 7	1968-01	-	27	-	-
USSR	Venus 1	1961y	7	-	-	-
"	" 2	1965-91	9	-	-	-
"	" 3	1965-92	9	-	-	-
"	" 4	1967-58	10	-	-	-
"	" 5	1969-01	11	-	-	-
"	" 6	1969-02	11	-	-	-
"	" 7	1970-60	13	-	-	-
"	" 8	1972-21	14	-	-	-

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			<u>A</u>	<u>B</u>	<u>C or D</u>	<u>E or F</u>
USSR	Venus 9	1975-50	16	-	-	46
"	" 10	1975-54	17	-	-	46
"	" 11	1978-84	20	-	-	-
"	" 12	1978-86	20	-	-	-
USA	Viking 1	1975-75	17	-	-	44
"	" 2	1975-83	17	-	-	45
"	Voyager 1	1977-84	18	-	-	-
"	" 2	1977-76	18	-	-	-
USSR	Zond 1	1964-16	8	-	-	-
"	" 2	1964-78	9	-	-	-
"	" 3	1965-56	9	-	-	-
"	" 4	1968-13	-	27	-	-
"	" 5	1968-76	-	27	-	-
"	" 6	1968-101	-	28	-	-
"	" 7	1969-67	-	29	-	-
"	" 8	1970-88	-	30	-	-

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